~~SECRET~~
~~SECURITY INFORMATION~~

43-1/139

UNCLASSIFIED

"PROJECT QUICK FIX"
SUMMARY REPORT OF SHORT TERM IMPROVEMENTS TO THE TACTICAL AIRCRAFT CONTROL AND WARNING SYSTEM

Report Number R-43

June, 1953

Work done by:

D. J. Boaz
G. M. Cate
L. S. Lavatelli
D. Lazarus
E. E. Miller
A. E. Murray
L. Streff

Report written by:

L. S. Lavatelli
D. Lazarus

CONTROL SYSTEMS LABORATORY
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS
Contract DA-11-022-ORD-721

UNCLASSIFIED

Numbered Pages: 139

~~SECRET~~
~~SECURITY INFORMATION~~

~~SECRET~~

UNCLASSIFIED

per letter dated 7 Sep 61 - H. J. Rockafeller - H. Ronnmonth A# 2145 R/C

CONTROL SYSTEMS LABORATORY

~~"PROJECT QUICK FIX"~~
SUMMARY REPORT OF SHORT TERM IMPROVEMENTS TO THE TACTICAL AIRCRAFT CONTROL AND WARNING SYSTEM

Report Number R-43

June, 1953

Copy 26 of 200 copies

Downgraded to Confidential as authorized in letter dated 12/21/54 from Capt. John F. Myron, Signal Corps contracting officer

UNIVERSITY OF ILLINOIS · URBANA · ILLINOIS

UNCLASSIFIED ~~SECRET~~ ~~Confidential~~

Security Information

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ABSTRACT

This report summarizes the results of a one-year investigation of simple short-term improvements to a Tactical Air Control System. A description is included of the equipment assembled to produce an up-to-date composite high-capacity display of target information gathered by a network of radars associated with a Tactical Air Direction Center, and of the operational tests of the system carried out at Pope Air Force Base in April, 1953. The report also discusses the limitations of the equipment and suggests improvements for field applications.

FOREWORD

This report is the final report of the Quick-Fix program of the Controls Division of the Control Systems Laboratory. The primary concern of the Controls Division is the automatic processing of radar data for tracking, display, and control of aircraft under the surveillance of a radar network, and involves a long-range development program. As an outgrowth of the basic work undertaken for the long-range development, an interim program, known as Project Quick-Fix, was undertaken.

There have been three earlier reports on the Quick-Fix program. The first is Control Systems Laboratory Report R-23, which contains a series of proposals for the interim solution. Control Systems Laboratory Report R-25 describes the basic physical principles of the optical target position indicator but does not describe the final form of this device. The best summary to date of the Quick-Fix program is the brochure 406078 prepared by the Ninth Air Force Communications and Electronics staff for distribution during the field tests.

I. INTRODUCTION

In the spring of 1952, two observers from the Control Systems Laboratory attended part of the Long Horn maneuvers in Texas. They were able to witness the Tactical Aircraft Control and Warning System in great detail. The shortcomings of the system were clearly recognized and delineated by the TAC Operations personnel who felt the urgent need for a short-term improvement program. The Quick-Fix program embodied only those principles which could be realized at once with existing or simply developed techniques and equipments.

The instrumentation of the Quick-Fix program was completed in six months at a cost of $50,000. The program required the service of about five full-time people and the shop facilities of Control Systems Laboratory. The equipment was taken to Pope Air Force Base on February 17, 1953, for installation and test. The field tests were completed on April 24, 1953. A detailed history of the project is given in Appendix I.

II. PRESENT TACTICAL AC & W SYSTEM

A. Description

The present Tactical AC & W system is shown schematically in Figure 1. A network of radars is used to survey an area of roughly 300 miles of front and 200 miles of depth. The radar information is collected at Tactical Air Direction Centers (TADC) and passed back to the Tactical Air Control Center (TACC) and Joint Operations Center (JOC) for evaluation. Decisions made at the TACC-JOC are forwarded to the TADC's for detailed action and control.

The forward light-weight radar units (LWRU) report by voice to a TADC where there is a large heavy-weight search radar. The filtered data from several LWRU's, usually two, and the heavy-weight unit are combined and displayed on the TADC plot board as a clear picture of the air situation. The information of the clear picture is then told by voice to the TACC-JOC where it is mixed with the clear picture information being produced at other TADC's. This system is basically the same as that used during World War II. Figure 1 shows in detail how the radar information passes through several human beings before it is displayed as a plot on the clear picture.

At the LWRU, a scope observer detects and follows all aircraft in his sector of responsibility. He tells the range and bearing of the aircraft to a plotter. The plotter enters these target coordinates on a polar board

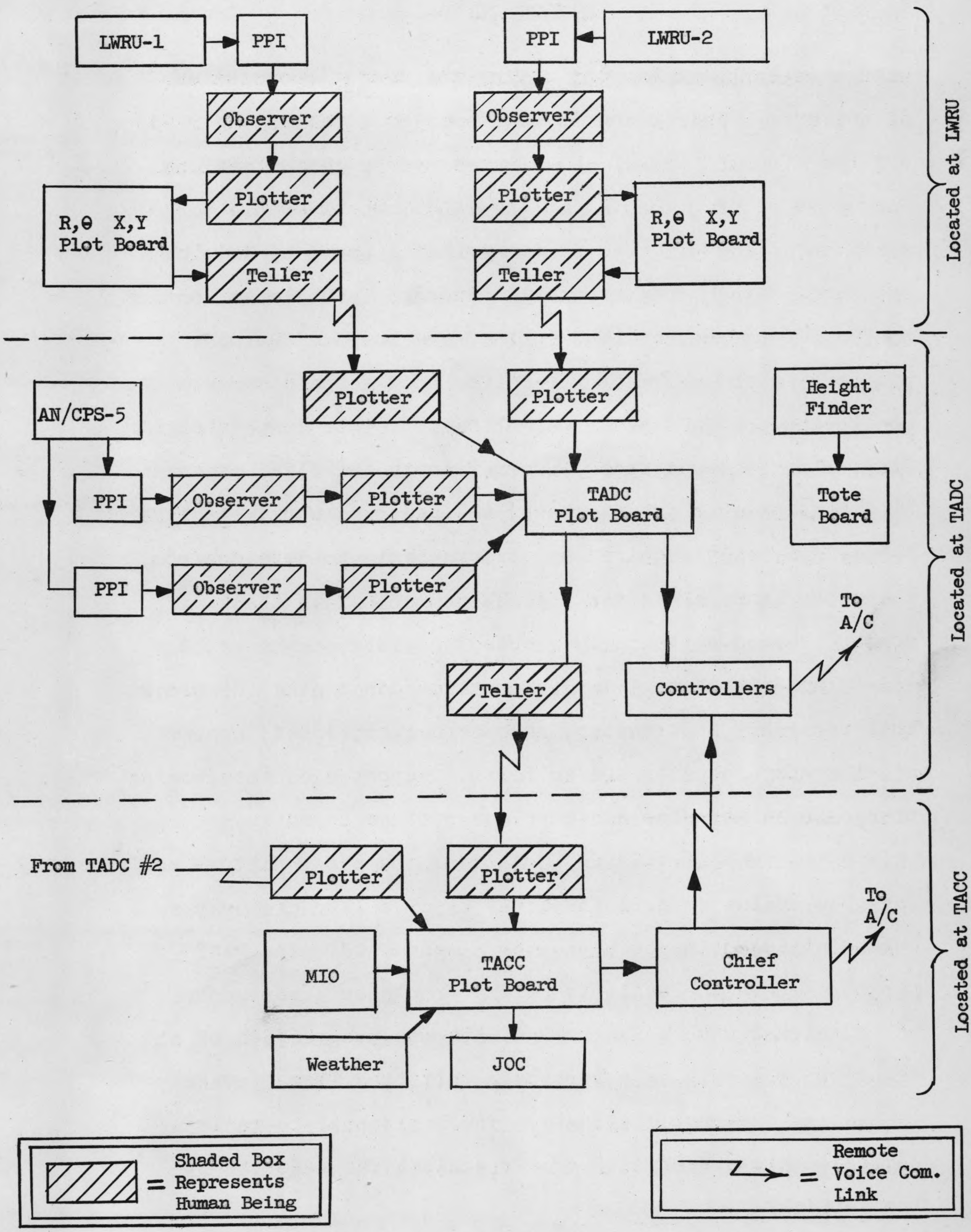


Fig. 1. Present Tactical AC&W System

with a rectangular overlay giving the georef coordinates of the area. This board is monitored by a teller who reads off the aircraft georef coordinates over a communications link to a plotter located at the TADC. The TADC plotter plots on an edge-lighted vertical Lucite board by writing backwards with a grease pencil. Another TADC plotter enters the data from another LWRU on the same board. Two more plotters enter information received from scope observers monitoring the TADC heavy-weight radar. This composite display of filtered radar information is the clear picture of the air situation as seen by the radar network. As radar echoes are newly acquired and tracks begin to develop from the plots, they are given a track number. This track number is used to identify succeeding plots on the track and to associate ancillary information concerning the track. This ancillary information, such as height, speed, number of aircraft, identity and so forth, is posted on tote boards placed on either side of the clear picture board.

A teller at the TADC, monitoring the clear picture and the tote boards reports the activity of all tracks over a communications link to a plotter at the TACC. The TACC plotter enters the activity of the tracks on a horizontal board, either with chips to indicate the progression of a track or by labels on a vertical "Christmas Tree" device indicating the ancillary data. The horizontal board is a composite picture of all the air activity as reported by the TADC's.

B. Deficiencies of the Present System

Because all information is told by voice, the system has a limited traffic handling capacity. Under high traffic conditions, it is inherently impossible to tell all the activity and some tracks will be lost. Moreover, the tracks that can be handled by the system under such saturation conditions become confused easily, because the scope observer, who is at the beginning of the information chain, cannot distinguish between new plots and reports on firm tracks.

The use of voice telling and hand plotting methods also results in large and unpredictable time delays in the communication of radar information. Reports from the LWRU must pass through four individuals before they appear at the TADC board, and delays of many minutes are common. In cases of simultaneous observation of a single target by two radars, such as an LWRU and the TADC radar, the difference in time delay occurring in the two reporting channels can result in the target's appearing as two targets on the clear picture, separated by a distance proportional to the time delay and target velocity.

Additional positional errors are introduced in the production of the clear picture by the various scope observers, tellers, and plotters, each of whom must estimate coordinates.

Because of these limitations, the vertical board of the TADC is of little value to the controllers located there, since the information it displays is incomplete, inaccurate, and out of date. At the TACC board, the information is degraded even more, since additional steps of telling and plotting are required to transfer the information from the TADC board.

To obtain even minimal operating efficiency, the present system requires long training periods because of the wide variety of different procedures which the operations crew must master. With rapid turnover of personnel, the efficiency of the system is poor.

The present system, though patterned after that used in World War II, has a considerably more difficult situation to display, because the higher speeds and smaller radar cross-section of modern aircraft require a network of radars rather than a single radar to obtain adequate coverage.

III. SUGGESTED SHORT-TERM IMPROVEMENTS FOR THE TACTICAL AC & W SYSTEM

Since the best radar information exists at the TADC in the present system, the most immediate and striking improvements can logically be effected there. The following facilities, shown in Figure 2, are required for efficient operation of the TADC, as discussed in Control Systems Laboratory Report R-23.

1. Automatic data transmission equipment should be provided between the TADC and its associated LWRU's for re-creating, at the TADC, PPI pictures of the outputs of the LWRU's. This equipment should operate without appreciable time delay using existing field voice communication facilities and radar units.

2. The TADC should be provided with devices for rapid and accurate production of a high capacity, filtered, composite picture of the air situation as seen by its network of radars. This clear picture should display all the rapidly changing variables of the aircraft under surveillance, such as position and direction of tracks, together with track numbers referring to a tote board, where slow variables such as height, speed, detailed identity, status, size, call sign, etc., are displayed. To minimize confusion during saturation, the scope observer must be able to distinguish between previous tracks and new plots as they appear.

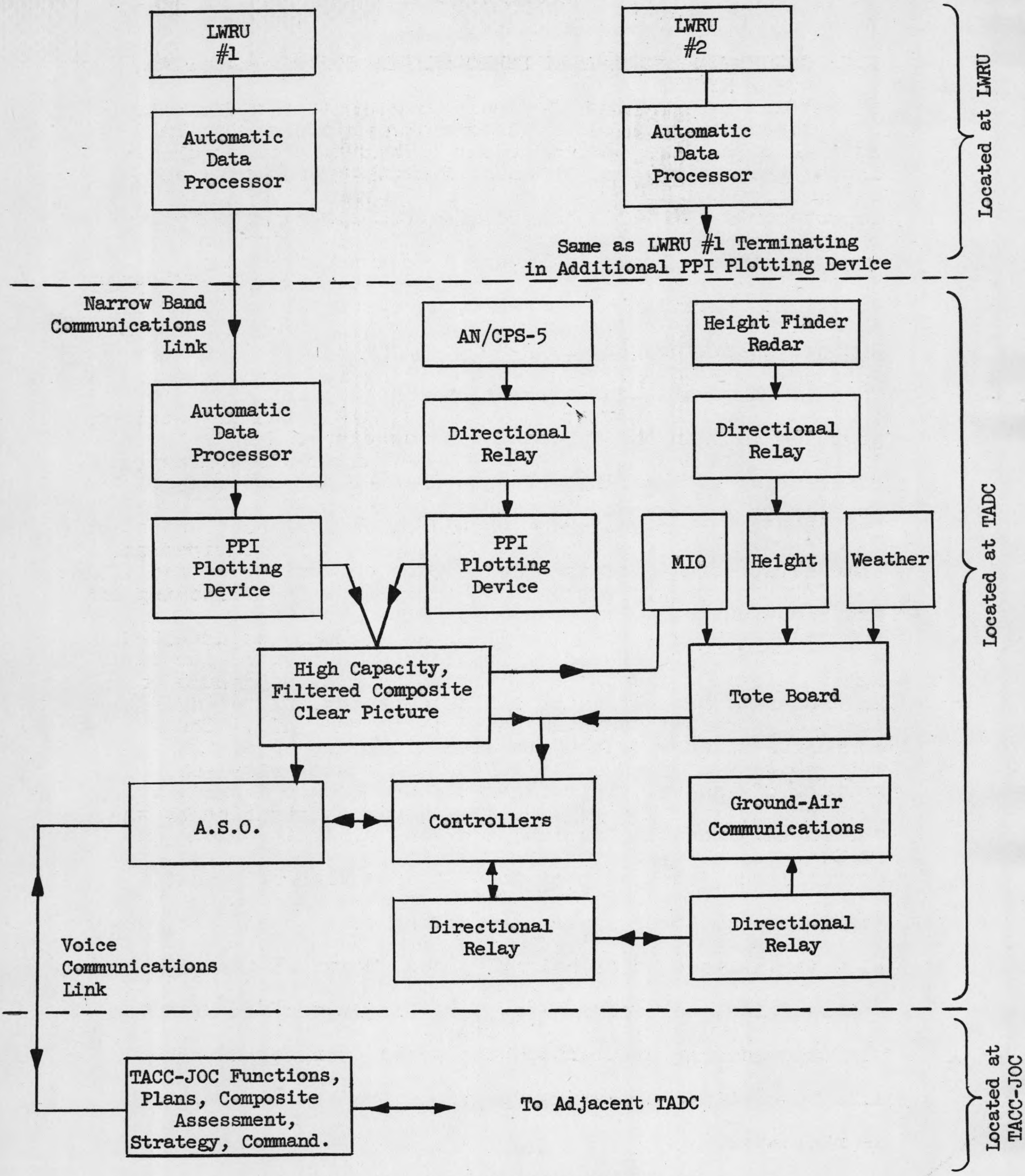


Fig. 2. Suggested TAC AC&W System.

3. The personnel of the TADC should be protected from air attack by remoting the operations section a distance of several miles from the radar and communications antennas, using directional relays.

4. The TADC should be provided with a Movements Identification officer (MIO) facility to permit most rapid and efficient identification of targets as they appear on the clear picture.

5. The TADC should be provided with a weather station to permit operations in the event of failure of communications with the TACC.

6. An Air Surveillance Officer (ASO) is required at the TADC to perform preliminary assessment and filtering of the data transmitted to the TACC. The amount of detailed radar data told should be severely restricted because of the limited track handling capacity of the TACC. The TADC should be given a limited scramble authority for intercepting hostile raids subject only to negation by the TACC.

IV. IMPLEMENTATION OF SHORT-TERM IMPROVEMENTS

A. Equipment Assembled for Field Tests

The Quick-Fix program of the Control Systems Laboratory was confined to implementation of the technical suggestions made in sections III (1) and (2) only, since the other suggested improvements, which involve changes in emphasis and policy, were outside the scope and responsibility of this laboratory. A block diagram of the operational Quick-Fix equipments employed in the TADC network is shown in Figure 3. A detailed technical description of the equipment is given in Appendix II. The following paragraphs describe briefly the functions of the Quick-Fix equipments shown in Figure 3.

The basic problem in transmitting radar information over a narrow band audio channel is to compress the inherently wide band video signal of the radar. The Rafax bandwidth compressor achieves this compression by storing on the phosphor of a suitable cathode ray tube (CRT) successive intensity modulated radar range sweeps. Thus, the successive radar returns indicating the presence of a target are integrated to form just one blip of light on the face of the CRT. The radar range sweep on the face of the CRT is scanned optically at a slow rate by a photocell looking through a slit. The output of the photocell contains the original radar range information as a slowed down video (SDV) signal. The slit width determines the range resolution

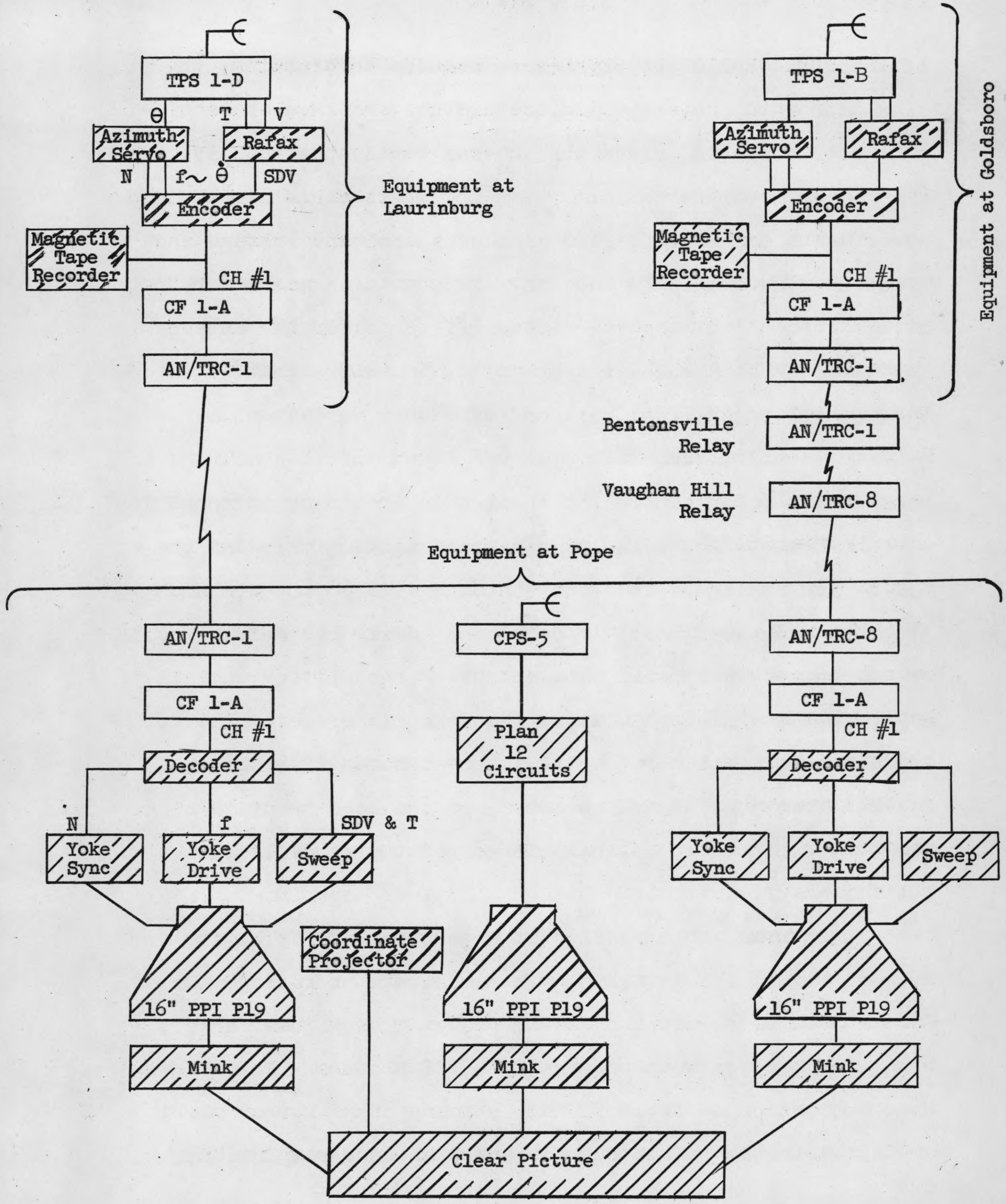


Fig. 3. Block Diagram of Quick-Fix Equipments (shaded)

of the SDV. While the SDV has no angular information, the slow scan rate, nevertheless, determines the angular resolution of the system, since the antenna turns continuously.

Since the radar antennas are not radomed and since field power units cannot be relied upon as a constant voltage and frequency source, it is necessary to provide a means for the deflection coil at the re-created PPI to follow the antenna position with the angular accuracy of the SDV signal. Windage on the AN/TPS-1D antenna can cause variations of $\pm$ 25 per cent in scan rate. It was found that a small synchronous motor can follow changes in frequency to about $\pm$ 25 per cent. Accordingly, a servomechanism following the 1:1 selsyn system of the radar antenna is used to turn an iron toothed wheel near the permanent magnet and driving coil of an ordinary earphone. The output of the driving coil is an approximate sinusoid, whose frequency is proportional to the antenna rotation rate. At the re-created PPI, this azimuth frequency signal is amplified and used to drive a small synchronous motor which is geared to the deflection yoke of the PPI.

In case the antenna changes speed too rapidly or the azimuth signal is disturbed by noise bursts or fading, the synchronous motor slips phase introducing an angular error, and it is necessary to reorient the PPI picture. This synchronization is accomplished by means of a "North" mark; an oscillator is pulsed on once every antenna revolution, and this "North" signal is used by conventional means to keep the PPI picture oriented to the same tolerance as the angular resolution.

The SDV signal, the azimuth frequency, and the north mark are combined in the encoder and put into a suitable form for transmission over a voice communication circuit. In the encoder, the SDV signal is standardized by means of a discriminator and a pulse shaping circuit.

The output of the encoder is connected directly to channel number 1 of a CF1-A carrier bay and to a magnetic tape recorder for playback of air activity at a later time. This carrier bay is a standard military terminal equipment used for providing four voice circuits on any communications link that can be carrier loaded.

At the TADC end of the communications link terminated with a CF1-A carrier bay, the decoder is connected to channel number 1. The decoder separates the three signals. The North signal is used for the deflection yoke synchronization. The azimuth frequency signal is used for the deflection yoke drive. The SDV signal is used both for the sweep trigger and video circuits of a modified Plan 12 Indicator.

Thus, the basic radar information is reassembled at the TADC to form a PPI picture almost identical to that at the LWRU. The narrow band picture shown in Figure 4 has several important features.

1. The information at the TADC is up to date; the maximum elapsed time between the receipt of an echo at the LWRU and the appearance of the target blip on the PPI at the TADC is one eighth of a second, the scan time of the Rafax.

2. It is a light on dark presentation; there is no gray background of noise because the SDV has been discriminated and standardized. The discrimination thus rejects noise, but owing to the standardization, weak target blips can still be seen with the same intensity as strong targets.

3. The long decay time of the integrator causes strong targets to be scanned several times, and thus, the number of blips per target is a measure of the target strength. (cf Figure 4)

4. The high coordinate accuracy of targets of the original PPI has been decreased slightly in the narrow band PPI. While the re-created PPI is inherently less accurate than the original, the information quality at the TADC is much better than if it had been voice told.

As shown in Figure 3, both LWRU's use similar equipments to transmit automatically the basic radar information to the TADC. The heavy weight CPS-5 radar at the TADC does not require the use of automatic data transmission equipment.

An important feature of the Quick-Fix system is the use of the British-developed P19 phosphor in all the PPI tubes. This phosphor (zinc activated magnesium fluoride) has a two-minute persistence, which enables the PPI observer to see a record of the last eight reports on a target in the case of a 4 rpm antenna rate. Moving targets are distinguished from permanent echoes by a trail of diminishing intensity. The length of the trail gives a measure of the speed of the aircraft, and the direction of the trail is the direction of the ground track of the aircraft.

The PPI tubes at the TADC of the three radars comprising the TADC network are mounted at the tops of three optical target position indicators, which have been called Mink units. The purpose of the Mink unit is to provide a rapid and easily operated means for filtering and displaying radar information, that is, for picking out of the raw radar picture the positions and directions of all air traffic and displaying this filtered information on a large, clear picture board.

The basic optical arrangement of the Mink is shown in Figure 5. A reflection of the PPI tube face is viewed by the observer looking down at a partially reflecting mirror. The tube appears to be below the mirror, and in the plane of this virtual image, a plotting surface is placed. Numbered chips are positioned on this plotting surface in coincidence with the images of the target blips that are being tracked.

The plotting surface is the plane surface of a plano-convex field lens. If light from the source passing through the field lens were reflected back through the field lens by a plane mirror, it would be refocused at the position of the projection lens. This arrangement insures that no matter

LEGEND FOR FIGURE 4

This photograph was made by opening the camera shutter for one revolution of the antenna, after sufficient history of the tracks had accumulated on the long persistence P19 phosphor. The radar is LWRU number 1 at Laurinburg. The data is Rafaxed SDV. The sweep length is 130 miles. The following list illustrates the interpretation of some of the tracks.

1. Second weak report on target at maximum (130 miles) range used.
2. Strobe from North synchronizing signal.
3. Trail from target which has faded on last scan.
4. First report on new track, average strength.
5. Track of jet aircraft entering ground clutter.
6. Track of slow aircraft entering ground clutter.
7. First reports on new tracks, weak returns.
8. Track of strong target entering null region of coverage (number of spots decreased from 4 to 1).
9. Two strong tracks crossing.
10. First report on new track, strong return.
11. Merging tracks.
12. Approximate location of Pope Air Force Base.

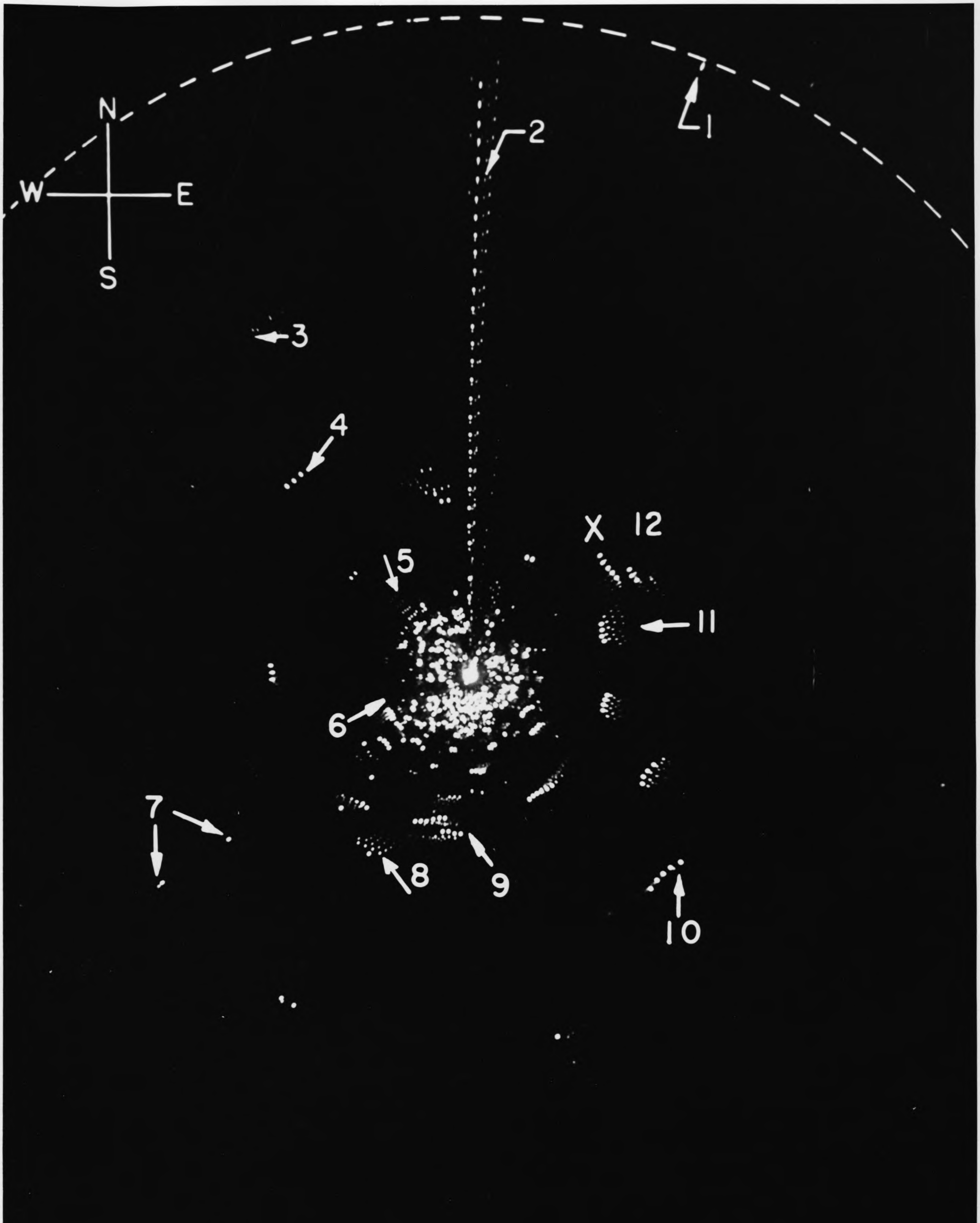


FIG. 4 PHOTOGRAPH OF RECREATED P.P.I.

SECRET

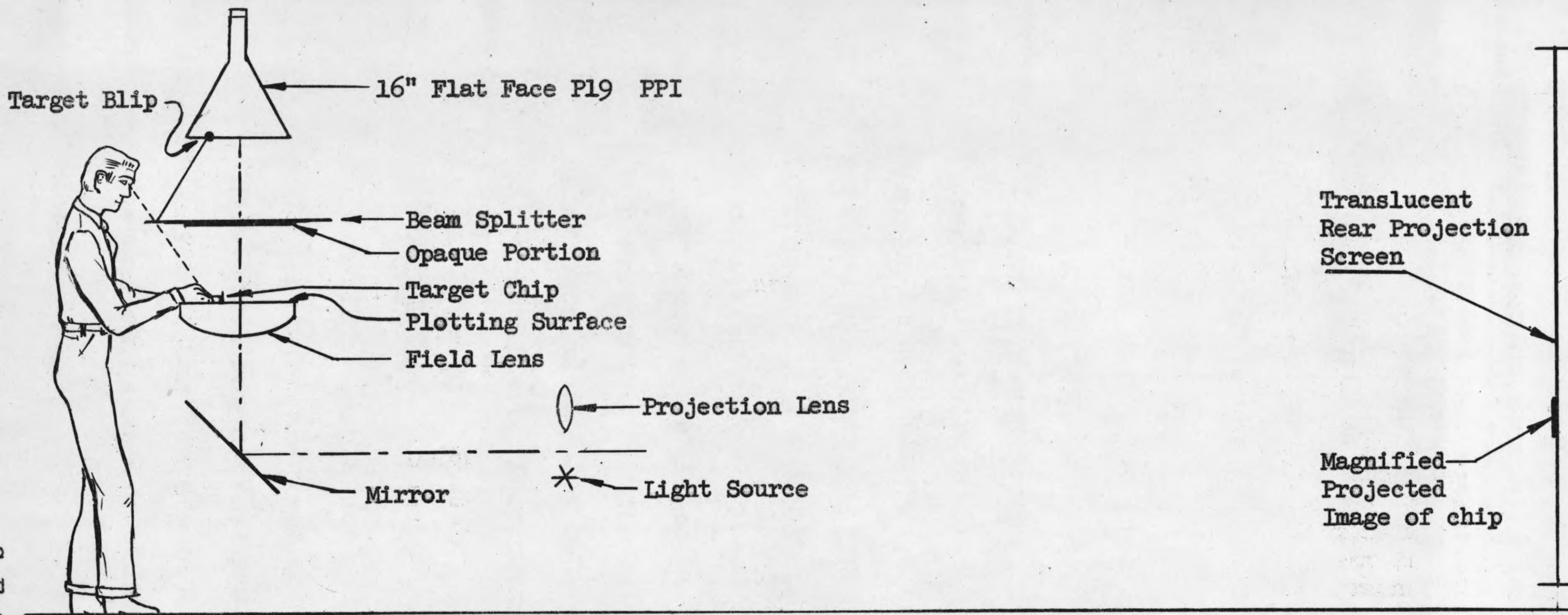


Fig. 5. Schematic Diagram of Mink Optics

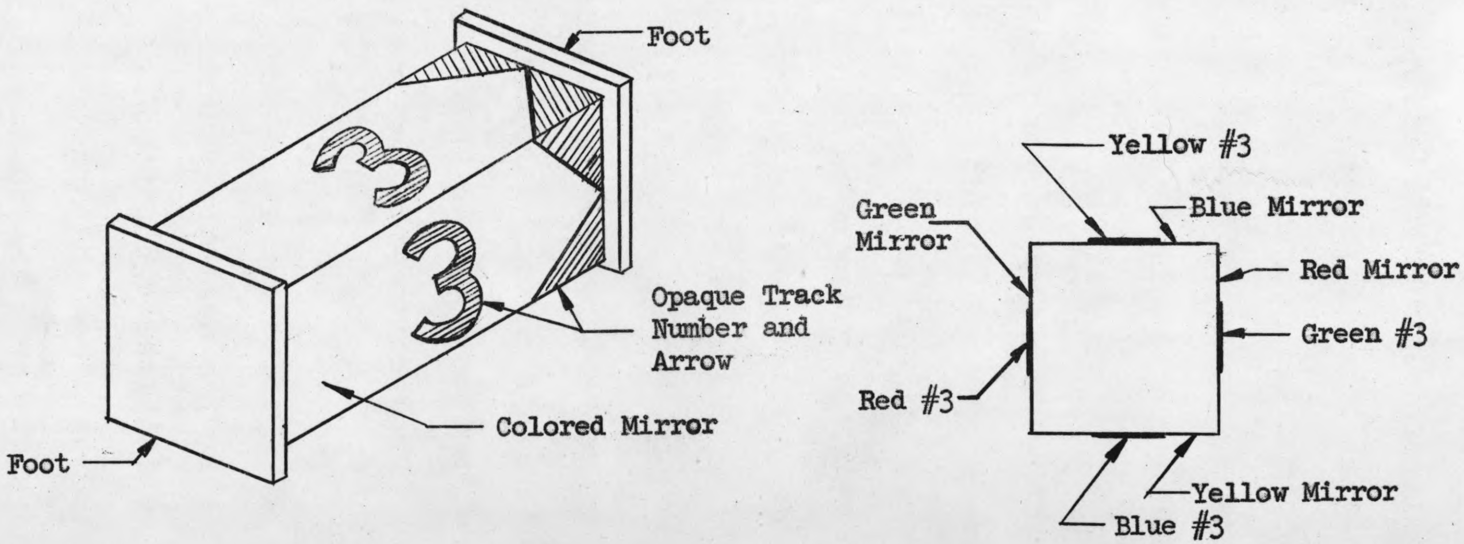


Fig. 6. Details of Chip Construction

SECRET

where the chip (a small plane mirror) is placed on the plotting surface, the light reflected from the underside of the chip will pass through the projection lens. The image of the chip is focused on the screen by a projection lens of proper focal length. The center portion of the beam splitter mirror is opaqued to prevent light from the source from falling on the CRT face.

The image of the chip appears bright on a dark background. This feature makes it possible to project on the same screen the optical outputs from several Minks simultaneously, as well as a grid giving the map coordinates of the area of the radar network. The grid, projected by a lantern slide projector, is used for the proper alignment and registration of the separate Mink outputs, as discussed in Appendix II.

Once the adjustments have been made, the conversion from polar to rectangular coordinates is automatic; the resulting picture is correctly composited; and a single target viewed simultaneously by two radars and plotted with their associated Minks appears on the screen as two completely overlapped images.

The chips are four-sided mirrors as shown in Figure 6, and bear the same track number on all four sides. This number as well as the tip portion of the chip are painted with opaque paint so that the image appears as a bright arrow with a dark number. The opaque paint is fluorescent and is illuminated by black (UV) light bulbs under the beam splitter.

This light gives high intensity colors without increasing the ambient light below the beam splitter. The observer sees the track number as a brightly colored symbol against the dark background of the mirror. As shown in the figure, the mirrors are tinted, the mirror tint agreeing with the number color of the opposite face. This arrangement indicates to the observer what arrow color he is projecting.

The four colors are used for classifying the identity of the aircraft such as red for bogey, green for friend, yellow for mission, blue for fade.

The function of the PPI observer at the Mink is to view the practically undelayed radar information displayed on the P19 tube, and to move the chips each scan so that the tip of the arrow is on the latest reported position of the target and the direction of the arrow coincides with the direction of the trail arising from the long persistence of the P19 phosphor. The observer can handle tracks over the entire area of the plotting surface. If the traffic becomes heavier, he can call for assistance, as the Mink is arranged to be operated simultaneously by one to four observers. The positions and directions of all targets are thus transferred to the clear picture without any voice communication. From the characteristics of the track on the PPI, the observer can furnish verbally on request ancillary information such as speed, number of aircraft, and IFF response.

The air situation, as seen by the network of radars, is thus displayed as a high traffic capacity up-to-date composite filtered clear picture projected on a seven-foot square translucent screen. A front view of part of the clear picture is shown in Figure 7. On either side of the screen are edge-lighted Lucite boards for toting height, number of aircraft, call signs, fuel status, etc. This ancillary information is referred to the proper track by the track number.

The clear picture is observed by the chief duty controller, his assistant (OPS B) and a number of duty controllers who are furnished with heavy-weight radar information on Plan 12 PPI's. The screen activity is monitored by tellers and recorders. Height information is obtained by the HRI operator and told to the height tote status clerk. The users of the clear picture data are physically separated from the producers of the clear picture. This arrangement is in consonance with the recommendations of the report of Project Charles and serves to reduce the confusion that is found in the usual TADC.

Finally, the TADC is provided with the usual ground-to-air military communication facilities as well as interphones between the OPS B and the Mink units.

Several important features of the Quick-Fix system should be noted:

1. All components are relatively simple and inexpensive. The simplicity insures reliability and easy maintenance of the system.

2. Attachment of the equipment at the radar sites is made by connection to existing plugs on the AN/TPS-1D and CPS-5 radars, and requires no modification of the radars.

3. All the information necessary to re-create the PPI presentation is transmitted over a single 2,500 cycle voice communication channel. The required communication facilities are typical field units.

4. Since the information is of audio bandwidth, it can be tape recorded. Once having tape recorded air activity, the tape can be replayed into the Mink units for training the operators without requiring additional aircraft flights. It can be replayed at higher speed into a PPI to permit rapid evaluation of an air battle. It can be replayed at slower speeds for re-transmission over a narrower bandwidth communication channel.

5. Once the slowed-down radar information is put on the voice channel, a PPI presentation can be re-created anywhere along the communications link. An arbitrary number of PPI displays can be operated simultaneously from the signal without degrading the picture quality. The information can be displayed on a properly modified Plan 12 controller's console for monitoring the Mink plotters and for detailed control.

6. The P19 PPI gives most of the features of multiple projection photography for track delineation, but without the mechanical, chemical, and logistic difficulties and with no inherent delay.

7. The clear picture is produced without voice telling, grease pencil plotting, or photographic processes.

8. The clear picture displays only the categories and the rapidly changing variables (position and direction) of the aircraft. It does not display slow variables (height, fuel status, etc.).

9. The clear picture is not cluttered with confusing grease pencil trails when the traffic density is high. There is no erasure problem when tracks are scrubbed or faded.

In conclusion, the system is geared toward a high traffic handling capacity by removing many operational delays of the old system.

B. Description of Field Tests

The tests of the Quick-Fix system were conducted at Pope Air Force Base, North Carolina, under the auspices of Ninth Air Force. Personnel and equipment were supplied by the Communications and Electronics Section, Headquarters, 9th Air Force, 507th Tactical Control Group, 8th Communications Group, 728th AC & W Squadron, and this laboratory.

An AN/CPS-5 search radar and an AN/CPS-4 height finder were located adjacent to the TADC on the Pope Air Force Base air field. A direction finding (D/F) network was also available but was not used during the tests. An AN/TPS-1D radar, located in a van at Laurinburg-Maxton airport, was used for LWRU number 1. An AN/TPS-1B radar, located in a tent near

SECRET

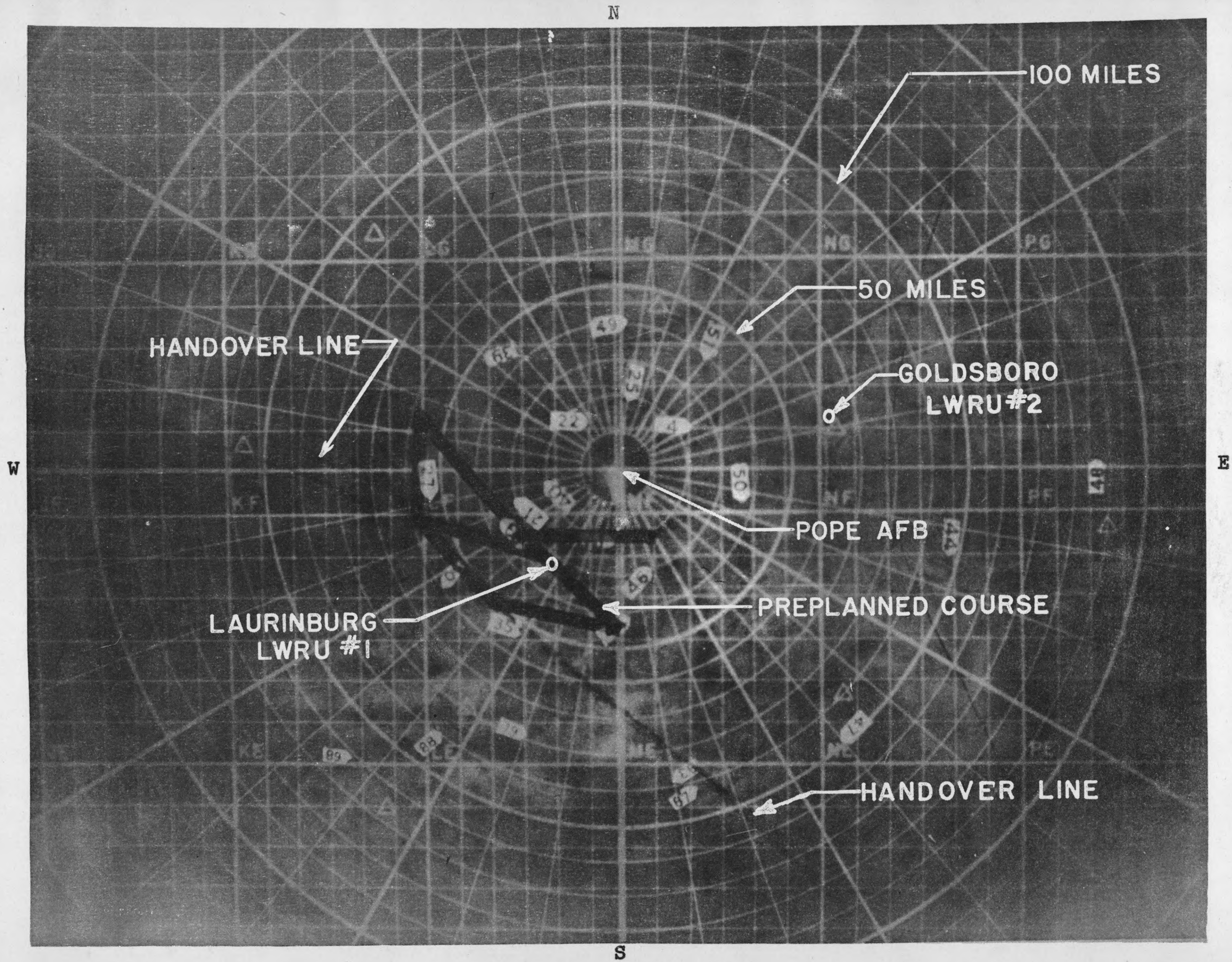


Fig. 7. Center Portion of Clear Picture Screen
The diameter of the 100 mile radius circle is 3 feet.

SECRET

43-35/139

Seymour Johnson Field, Goldsboro, North Carolina, was used as LWRU number 2. All radar units were shared with the normally operating TADC. Ground communications equipments, which were also shared with the normally operating TADC, consisted of carrier-loaded AN/TRC-1 and AN/TRC-8 equipment terminating in AN/TTQ-1 vans.

The Quick-Fix operations were carried on in a Jamesway shelter adjacent to the normal TADC. Illustrations of the sites and equipments are shown in Figures 8 through 16. As shown, part of the floor of the Jamesway was removed to provide a solid base for the Mink units.

A complete list of personnel who contributed to this program is given in Appendix IV. During operations, a crew of three officers and seventeen airmen was required for the TADC. Officer personnel served as duty controllers and chief duty controller. Airmen alternated in positions of Mink observer-plotter, tote board plotter, height teller (substituting for an HRI operator), OPS B, and recorders. The operation and maintenance of the equipments were handled almost completely by 728th Squadron personnel.

The internal communication facilities employed in the Quick-Fix TADC are indicated in Figure 17.

During a training period of approximately five days, initial plotting and control procedures were worked out. Major areas of responsibility for the Laurinburg and Pope Mink units were assigned on the basis of survey flights.

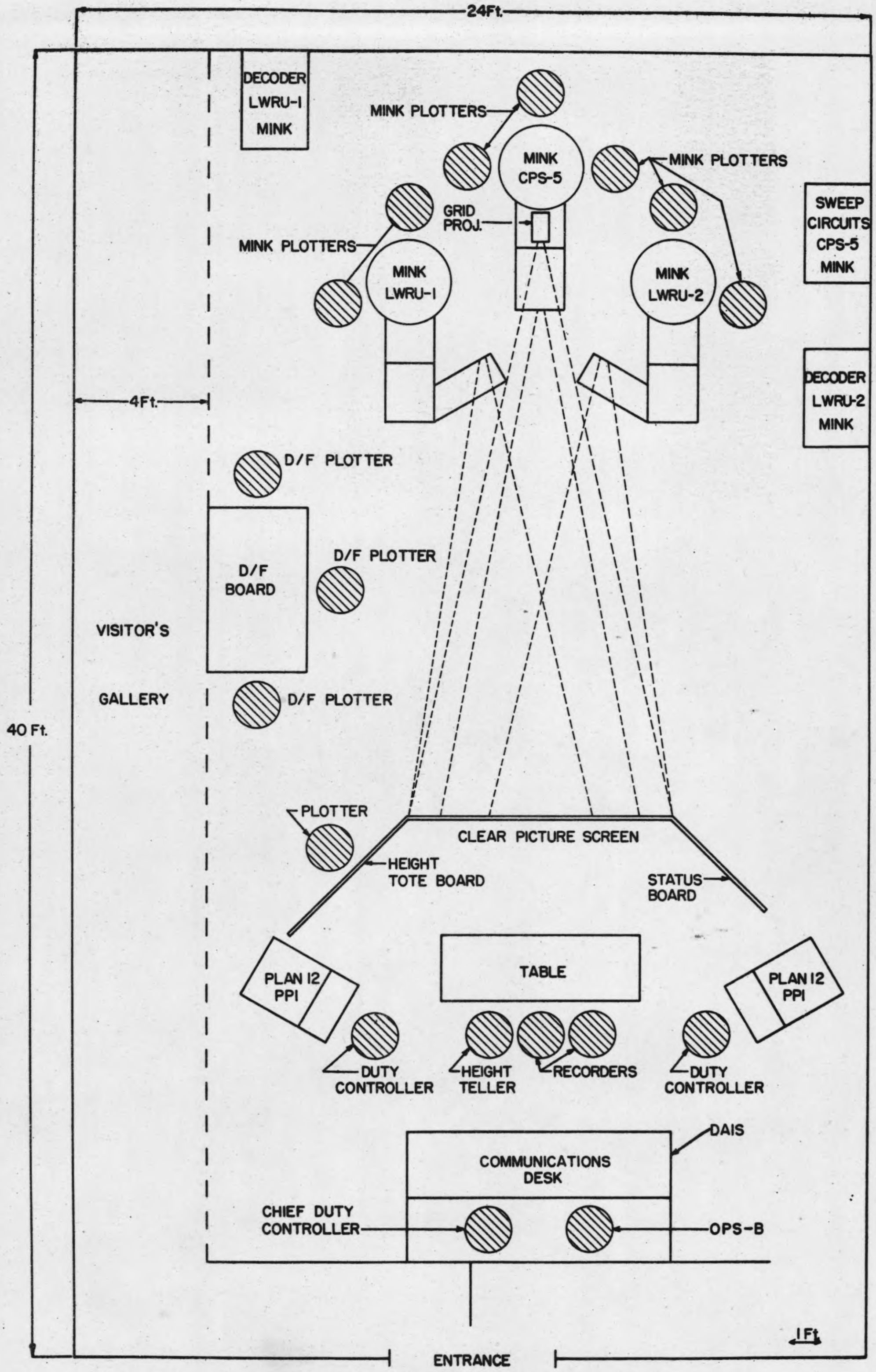


FIG. 8 PLAN VIEW OF QUICK-FIX TADC

SECRET

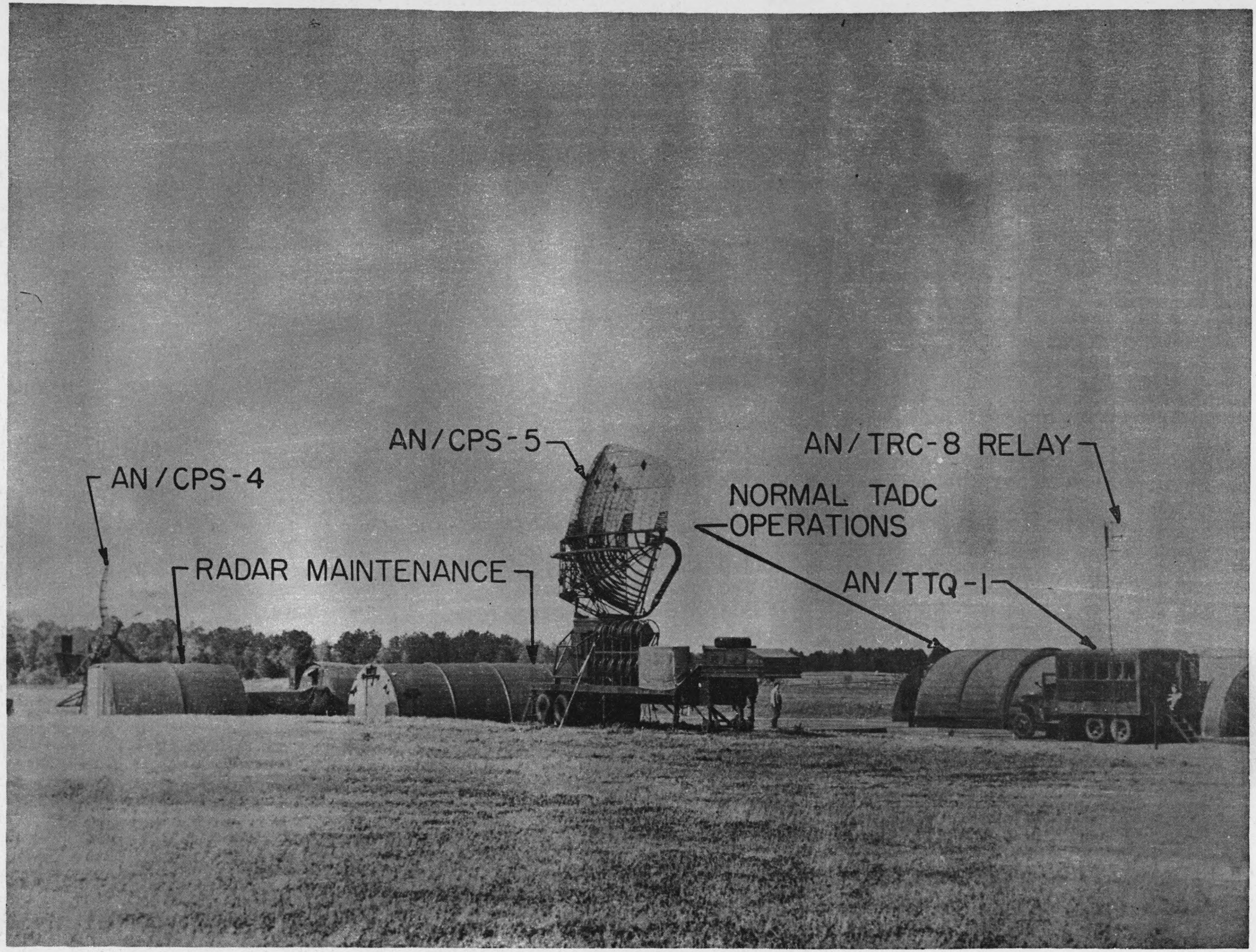


FIG. 9 POPE SITE

SECRET

SECRET

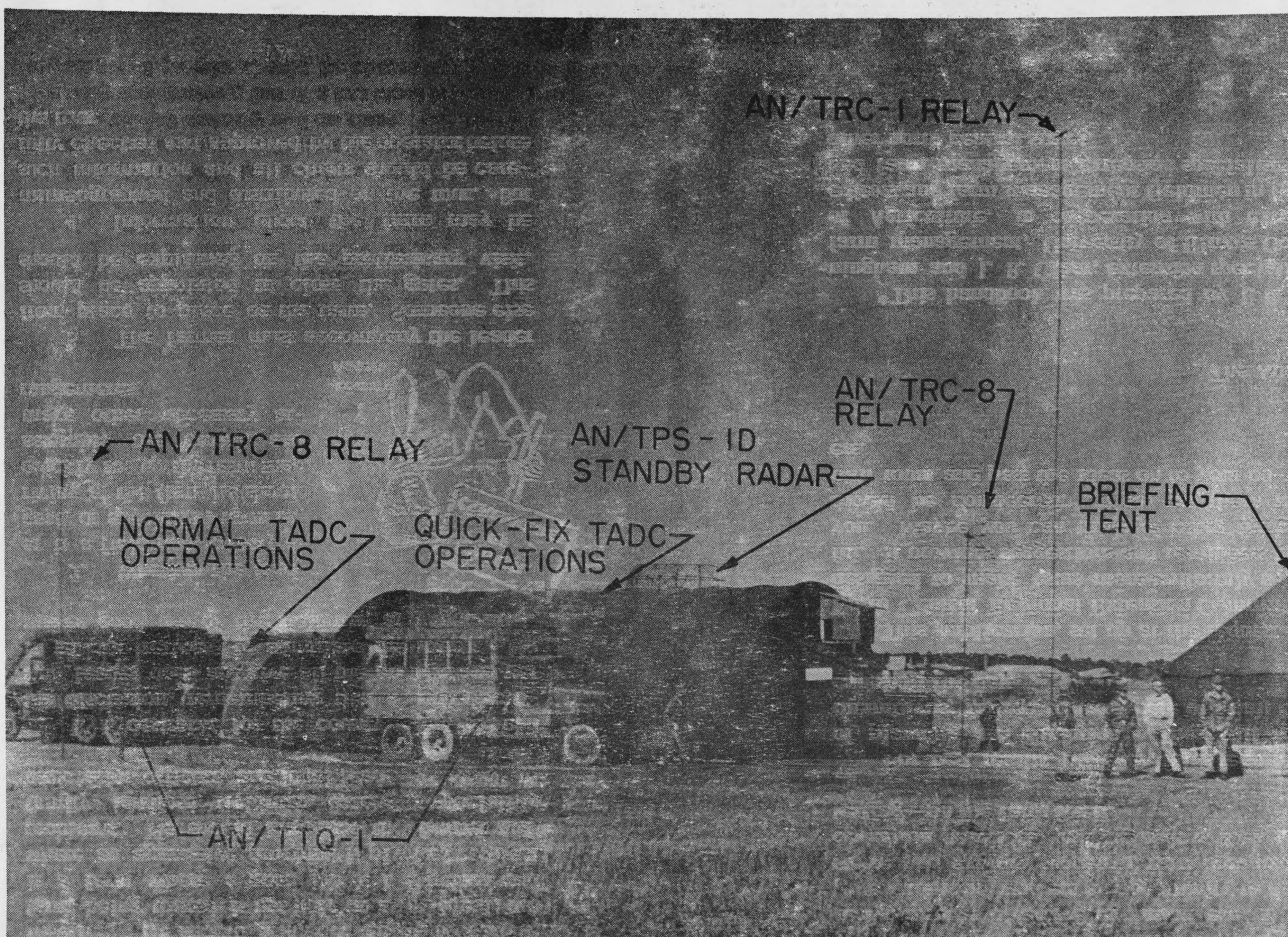


FIG. 10 POPE SITE

SECRET

43-39/139

SECRET

43-40/139

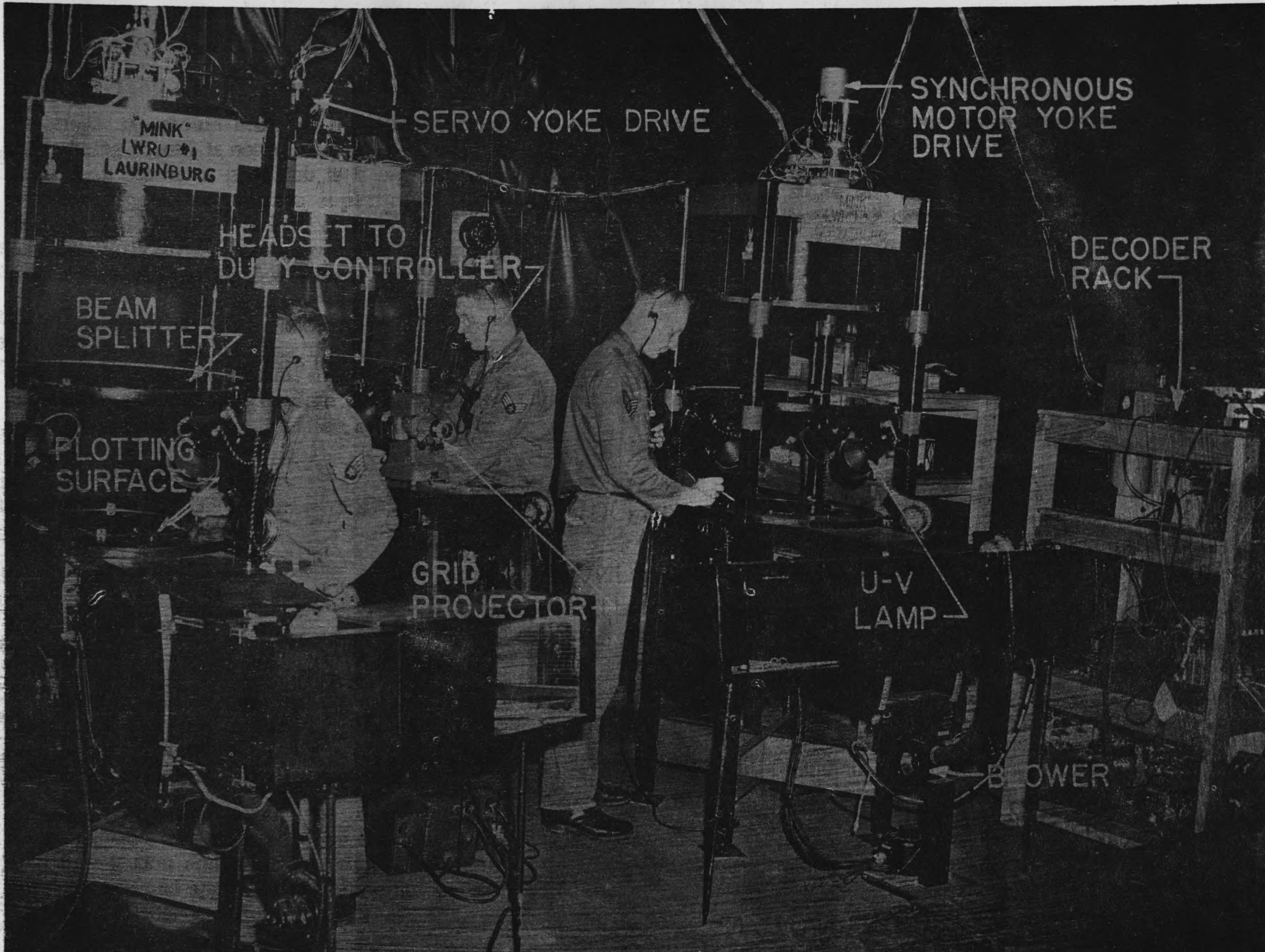


FIG. 11 POPE SITE — MINK UNITS

SECRET

SECRET

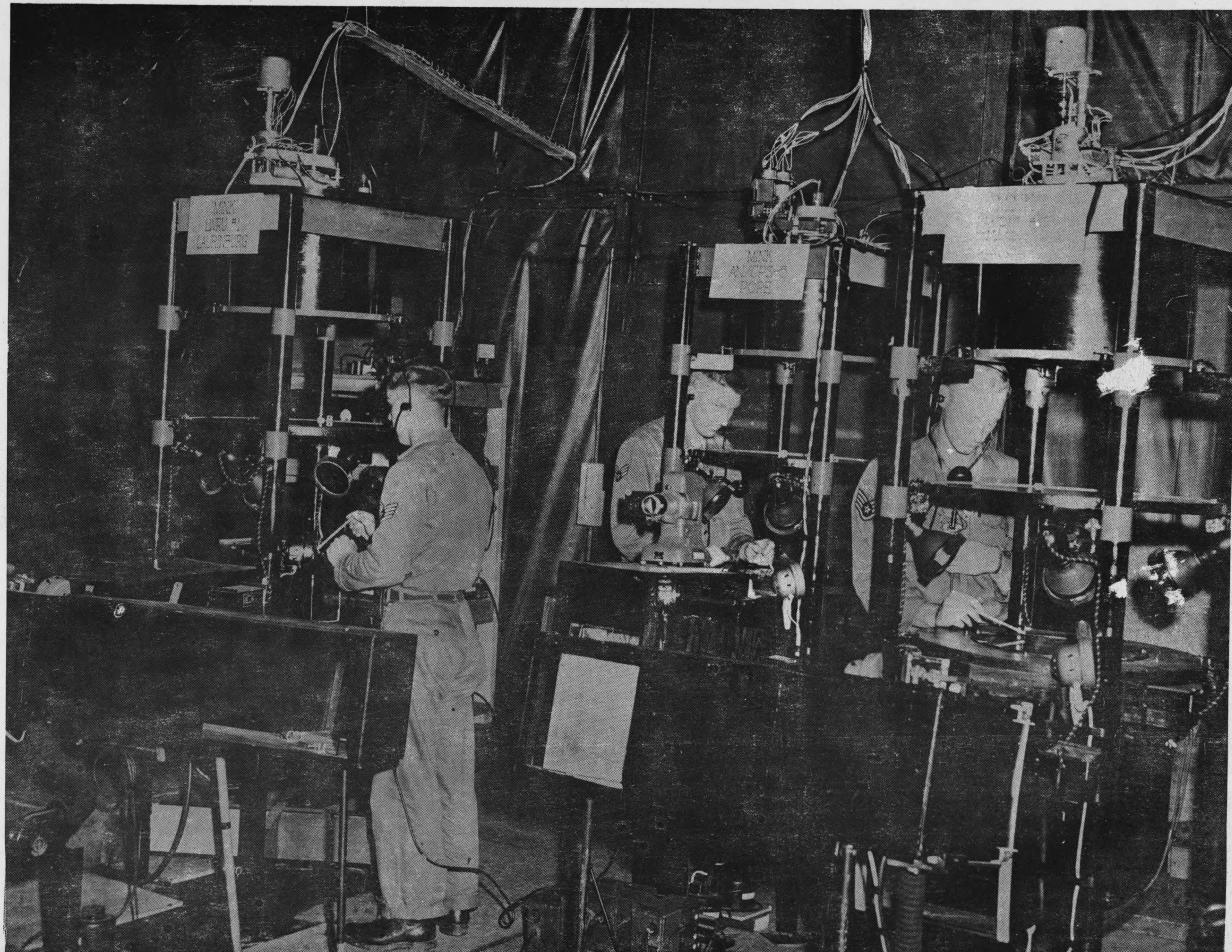


FIG. 12 POPE SITE—MINK UNITS

SECRET

43-41/139

43-42/139

SECRET

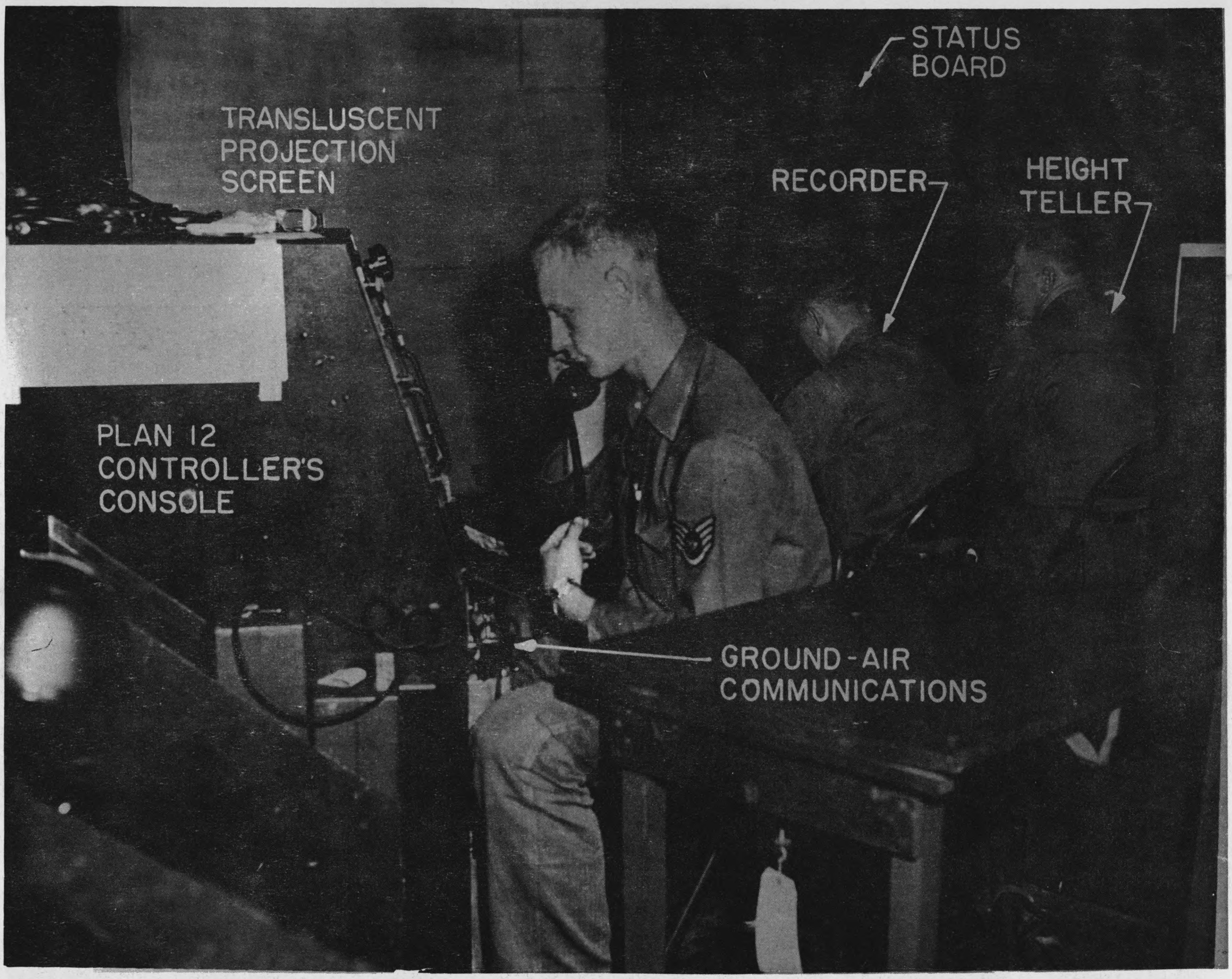
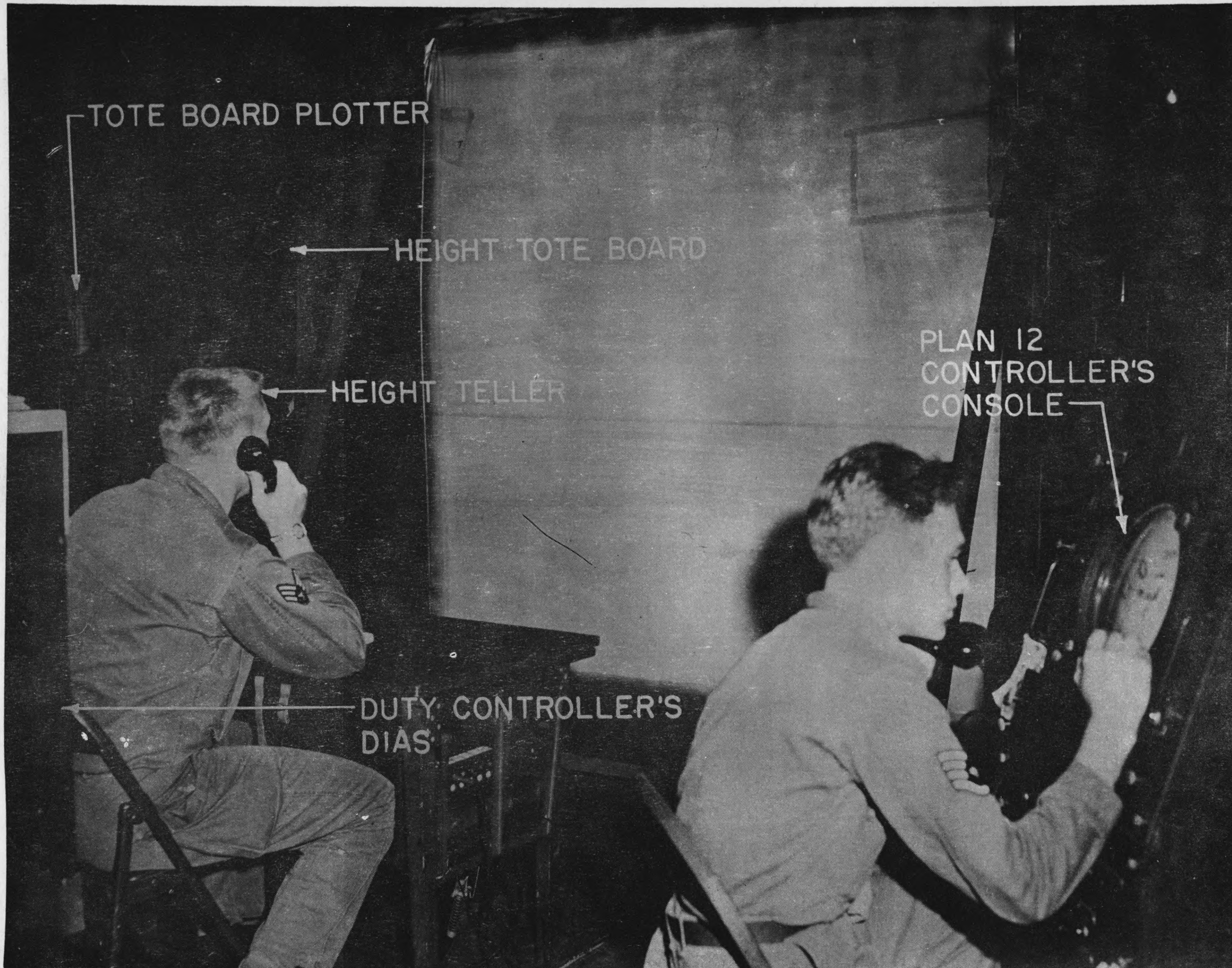


FIG. 13 POPE SITE—CONTROLLER'S SIDE OF SCREEN

SECRET

SECRET



SECRET

43-43/139

FIG. 14 POPE SITE—CONTROLLER'S SIDE OF SCREEN

SECRET

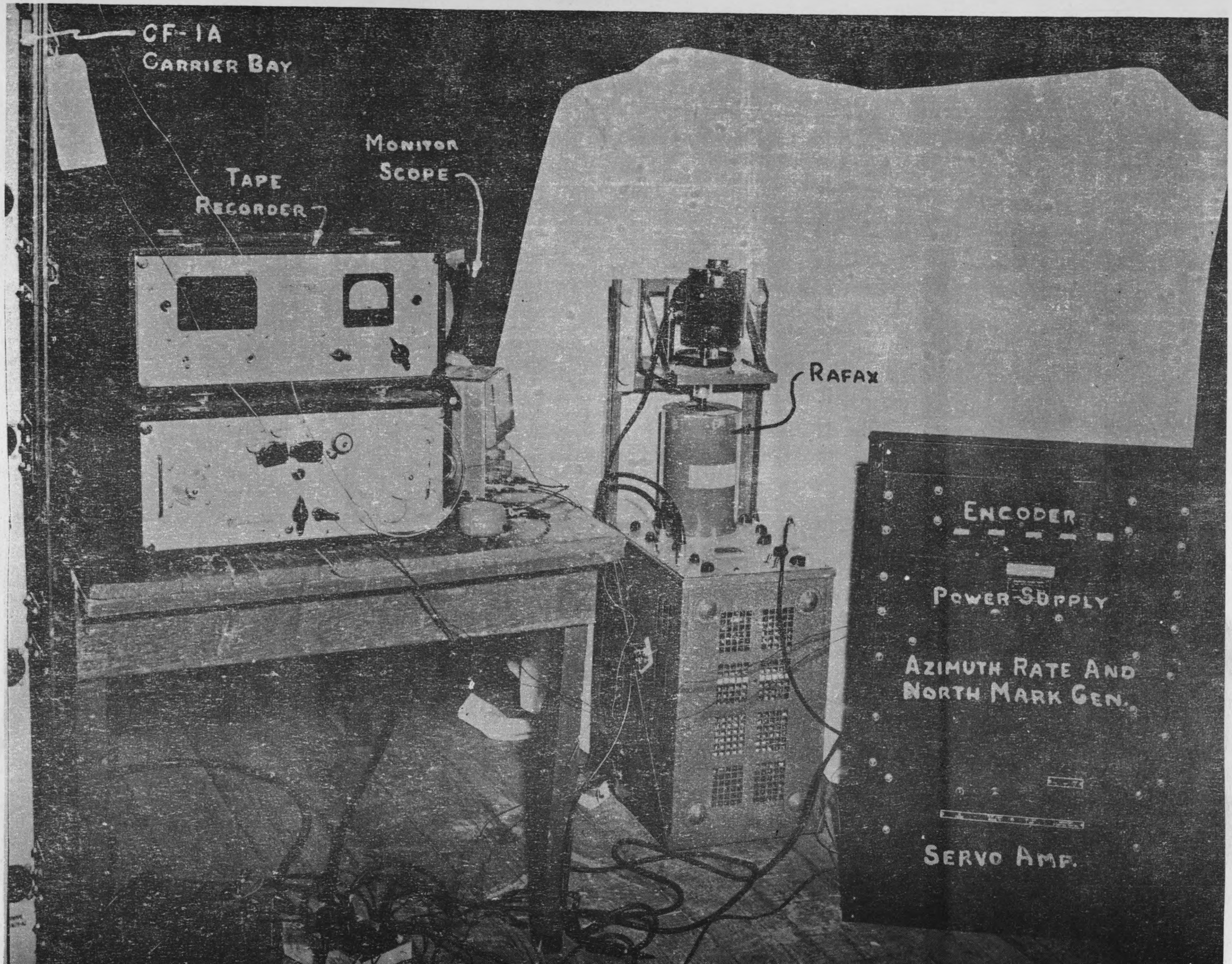


FIG. 15 LAURINBURG SITE—AUTOMATIC DATA TRANSMISSION EQUIPMENT IN COMMUNICATIONS TENT

SECRET

43-44/159

SECRET

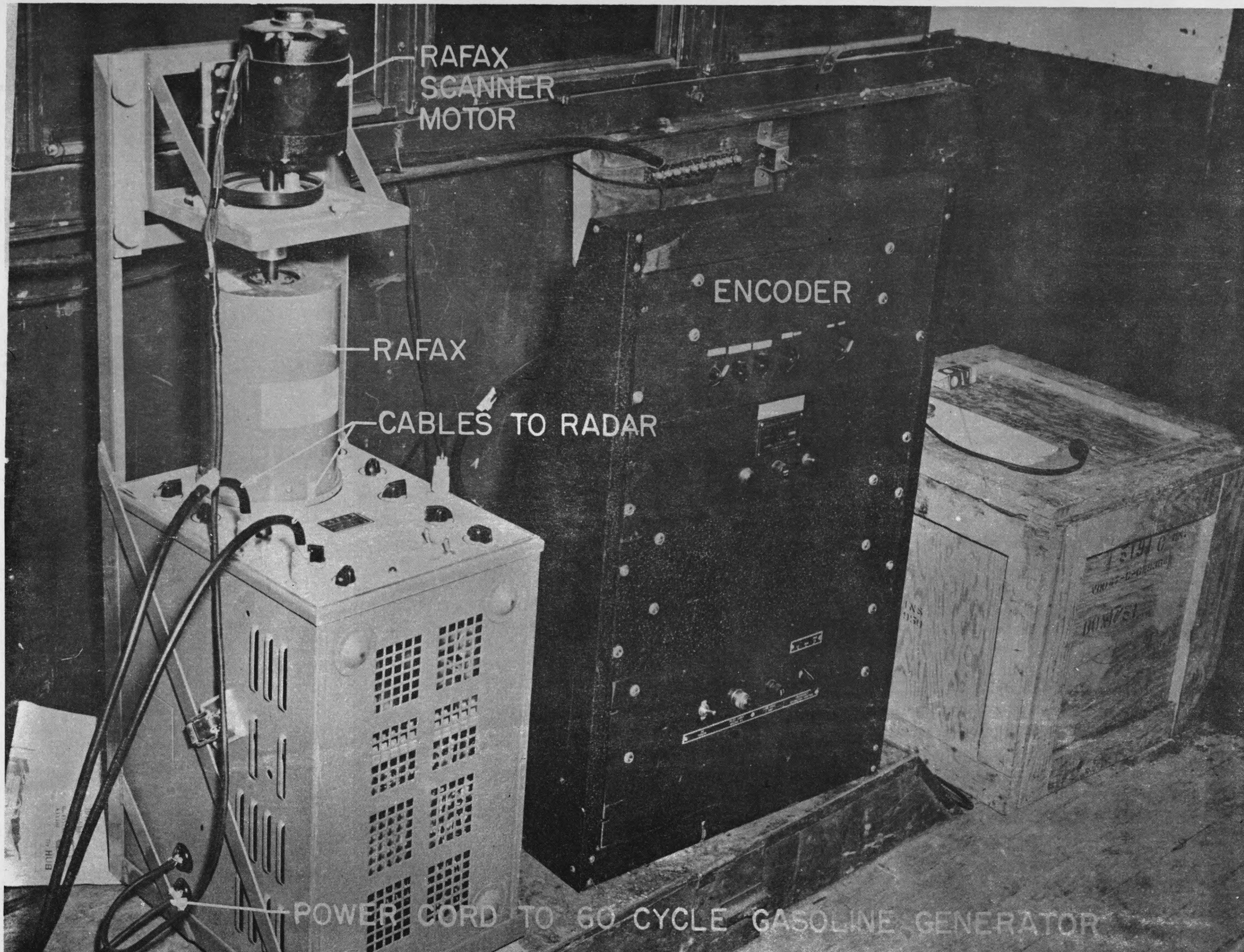


FIG. 16 GOLDSBORO SITE—AUTOMATIC DATA TRANSMISSION EQUIPMENT IN VAN

SECRET

43-45/139

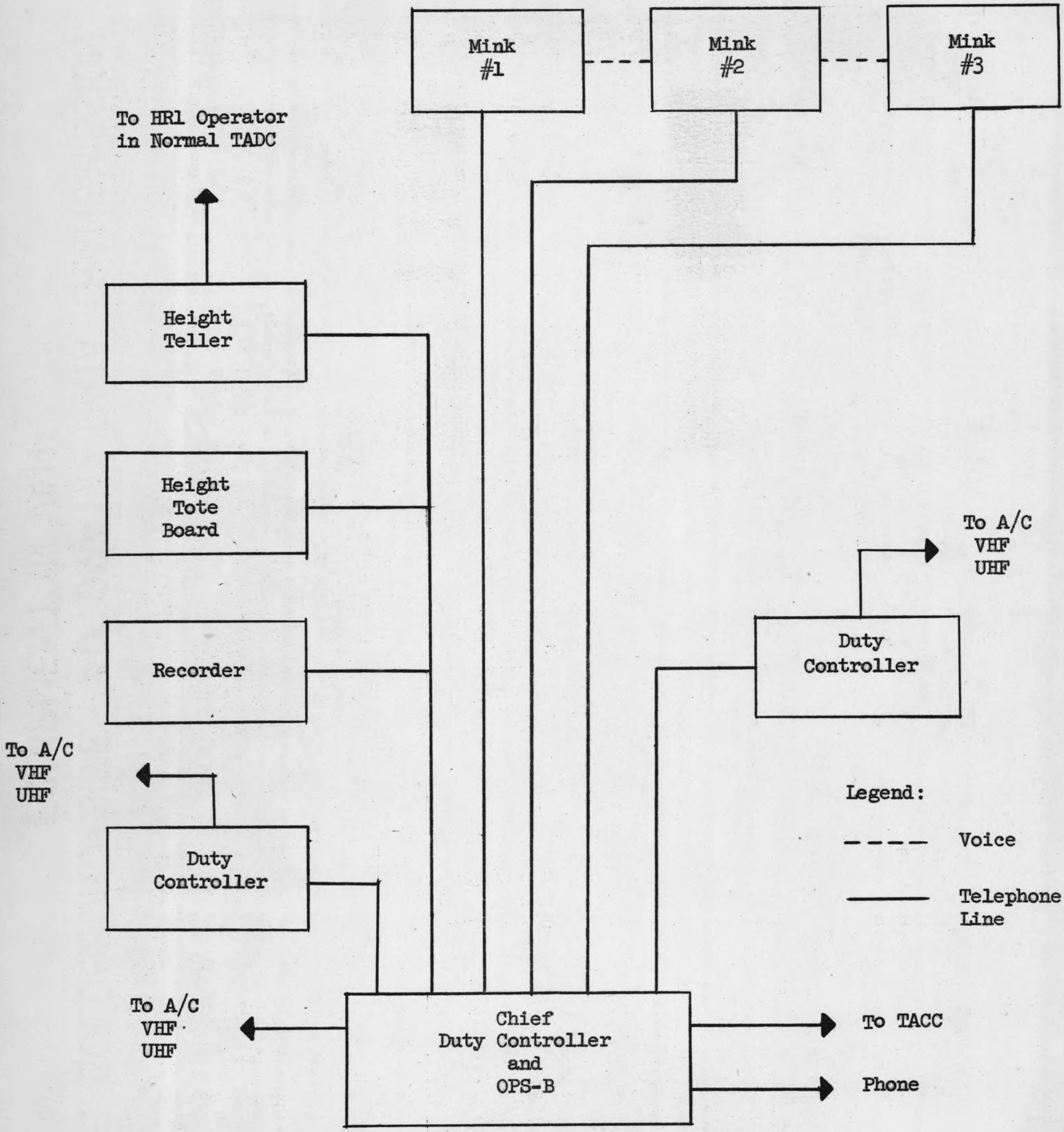


Fig. 17 - Quick-Fix TADC Internal Communications

A handover region for tracks moving between the Laurinburg and Pope areas was defined, after it was determined that proper superposition of tracks was obtained in the overlap region.

All tracks originating in the area of primary responsibility of the Pope Mink unit were carried with plotting chips numbered 1-70. Plots originating in the area of the Laurinburg Mink unit were carried with chips numbered 71-90. Later, after the Goldsboro communications link had been established, chips numbered 61-70 were assigned to that Mink unit. When a track was first noted near the handover region, it was plotted initially with an un-numbered blue chip. By observation of the clear picture screen, the plotter could easily determine whether this un-numbered chip overlapped a track which was being carried on another Mink unit. If the images superimposed, the plotter would request the original numbered chip from the other Mink unit. The plotters at the various Mink units could alert each other of approaching crossover conditions.

Tracks in regions of primary responsibility were plotted with colored numbered chips. Tracks were initially started in red to signify lack of identification. After an interval of about a minute, in which it was presumed that identification would have been effected (no IFF or MIO facilities were available during the tests), the chip was turned to green, implying a friendly aircraft. Mission targets, which were under the control of the Quick-Fix TADC, were carried in yellow. Tracks which had faded from radar coverage were carried in blue for a period of about two minutes before the chip was removed.

A priority procedure was used in the handling of yellow chips. Since these planes were under the control of the TADC, the Mink plotters moved these chips immediately after the radar beam had passed, using dead-reckoning procedures in the event of intermittent fading. The quality of this procedure was enhanced by notifying plotters of control instructions given to the aircraft. In the case of close proximity of yellow and an other chip, the other chip was delayed until the yellow chip had moved out of its path. These procedures insured that the clear picture information on mission targets was as accurate and up-to-date as possible. An additional procedure was sometimes used in the event of fading of radar reports on controlled targets in the overlap area between two radars. In such cases, the plotters, instead of dead-reckoning the chip, could request information from the adjacent Mink unit, whose radar might have the track under surveillance. By viewing the rear side of the projection screen, the adjacent Mink plotter would place an un-numbered yellow chip on his plotting surface so that the projected image of this chip superimposed with the image of the numbered yellow chip. He could then determine whether his radar could see this track, and give an assist to the original plotter until the blind region had been passed.

A variety of missions for the Quick-Fix TADC were arranged jointly by personnel of the 507th Group TACC and Headquarters 9th Air Force. These missions consisted of ground controlled intercepts and pre-planned controlled navigation. Ground controlled intercepts were accomplished both from CAP and from simulated ground scramble (delayed vectoring from 1,000 feet) using both jet and F-51 aircraft as intercepters against jet, F-51, C-47, and C-45 aircraft as hostiles. Intercept missions were successfully completed both by the controllers, using their PPI consoles, and by the duty controller using only the clear picture display.

Pre-planned controlled navigation missions of two types were carried out. In the first type, successive strikes at five minute intervals were effected on a single ground target by a number of aircraft. The aircraft after being first acquired, were vectored along a polygonal path, taking them around simulated flak areas and mountains. The planes would disappear from radar coverage during the ground strike, later reappearing for control back to base along a different polygonal path. This type of mission was successfully completed using both jet and F-51 aircraft, singly and in groups of two for up to twelve simultaneous missions involving twenty-four aircraft. Under such conditions, the chief duty controller simultaneously controlled eight of the missions from the clear picture display alone.

The second type of navigational mission involved simultaneous parallel strikes on each of seven different ground targets using seven different groups of aircraft which originated from different bases. The aircraft were navigated around simulated flak areas and obstacles along different polygonal paths such that each mission could complete its ground strike within a total interval of less than one minute. This type of mission was successfully completed.

C. Operational Results

The above missions were carried out as part of the daily operations of the Quick-Fix TADC during the two-week demonstration period. Quantitative operational evaluation tests were conducted by operations analysis personnel from HQ Tactical Air Force during a typical morning operation. Excerpts from the operations analysis is given in Appendix III. From this report, the following data were obtained over a typical ten-minute interval in the operations of the Quick-Fix and Conventional TADC's:

	Quick-Fix	Conventional
1. Total tracks reported on	23	13
2. Average tracks carried per minute	12.65	5.3
3. Average length of track	6.33 mins.	2.48 mins.
4. Total number of plots	450	37
5. Average plots/track	19	2.85
6. Average plots/minute	45	3.7
7. Average time between plots	18 sec.	98 sec.

At other periods during the tests, as many as fifty simultaneous tracks were carried on the clear picture of the Quick-Fix TADC without any evidence of saturation. The ratio of tracks carried on the Quick-Fix screen to that in the conventional TADC varied from 2 to 5. Mission tracks were usually carried without interruption for periods up to two hours.

The tracks in the Quick-Fix TADC could be kept accurately up-to-date, when the Mink plotters exercised sufficient care. On occasion, the chief duty controller was able to complete ground controlled interceptions, without a PPI display, using only his knowledge of aircraft positions and the clear picture information.

The optical compositing of the filtered outputs of the various radars in the network proved very effective. In one instance, an aircraft was controlled for about 70 miles in the region of overlap between the Pope and Laurinburg radars. This track was plotted on both Mink units. The two chip images overlapped to within two miles for the entire distance.

A considerable enhancement in the speed of detecting new targets was realized with the Mink units operating from the LWRU's. Since the SDV signal is transmitted with a standardized amplitude, all targets appear with the same intensity and no trace or background noise is visible. The resultant PPI picture is extremely clean, as shown in Figure 4, the targets appearing as sequences of light dots against a black background. In practice, tracks were often acquired by the Quick-Fix system several minutes before being reported by the conventional plot-tell methods.

During the present tests, tape recordings were made of the encoder outputs at both the Laurinburg and Goldsboro LWRU's. On replaying at this laboratory, the decoded picture appears to be identical with that observed at the TADC during the tests.

The overall reliability of the various electronic components of the Quick-Fix system was found to be adequate. The SDV and encoding equipments at the LWRU's were operated by airmen from the radar maintenance section of the 728th Squadron, and required only a few minutes lineup each day. During operations, the equipments at both the LWRU and the TADC operated unattended. The major source of difficulty during operations resulted from failure of field power generators and communications transmitters.

A single ECM mission was conducted against the Pope radar during the tests. The PPI tube with a P19 phosphor on the Pope Mink unit never reached a condition 5 (complete blindness in all directions) while the PPI tubes with P7 phosphors on the controller's consoles were in condition 5 for several minutes. On the P19 PPI, strong targets and ground clutter were always visible. This difference presumably results from the larger dynamic range of the P19 phosphor.

The long storage characteristics of the P19 phosphor also proved extremely valuable during operations. The Mink plotters were enabled, by the observation of long persistent trails on moving targets, to distinguish quickly between returns from aircraft and permanent echoes without using the MTI available on the radar, and to maintain track continuity through regions of intermittent fading.

V. CONCLUSIONS AND RECOMMENDATIONS

Many of the features of the present system seem to be applicable, without considerable change, to other radar network problems of the armed services, in particular to the systems of the Air Defense Command, Anti-Aircraft Artillery, Harbor Defense, and Marine Corps. It is probable that major redesign would be required for shipboard or airborne radars to take account of moving radar centers. For fleet problems, the Mink units would require redesign to be operated on shipboard in order that the chips and optics be stable during heavy seas and gunfire.

The Quick-Fix system proved effective in increasing the efficiency of the TADC operations within the framework of the present Tactical AC & W system. This effectiveness was gained by use of reasonably inexpensive and simple equipments, without increasing the personnel requirements of the TADC. However, it is important here to attempt to define the bounds of the Quick-Fix system, as demonstrated, in comparison with the features which are expected to become available in future semi-automatic and automatic control systems.

A. Limitations on the System

One of the major virtues of the Quick-Fix system is its simplicity, but this feature, which should be preserved in field equipments if rapid procurement is to be effected, places limitations on the extent of the system. The following may be considered as limitations imposed by the scope of the system, which cannot be eliminated without a considerable complication of the equipment:

1. This system provides no improvement in radar coverage or performance other than that which may result from faster data handling capabilities.

2. The system does not provide for improvement in close control capabilities, such as those involved in MSQ and GCA operations.

3. No change is made in the method of transmission and display of height or status data on aircraft.

4. This system does not appreciably reduce the personnel requirements of the TADC beyond the number required at present for telling of data, but uses personnel more efficiently to effect a considerably greater track handling capacity.

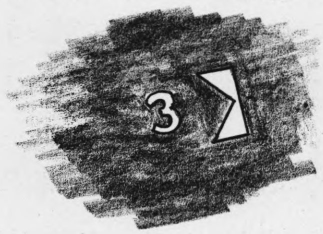
5. The system does not result in automatizing acquisition, tracking, and control operations at the TADC. These functions are still performed by people. The reliability and up-to-dateness of the clear picture are limited by the abilities of the observer-plotters.

6. The system is inherently limited in the azimuth resolution obtainable on targets viewed by the LWRU. This limitation arises from the integration process at the Rafax. Some degree of beam splitting could be achieved by the use of additional apparatus at the LWRU's. However, since the main function of the LWRU is to provide extended coverage

and early warning information, the large number of vacuum tubes required for beam splitting was not considered worth while.

The following limitations of the system are those which are inherent only in the present equipment and, as discussed in the next section, should be amenable to solution in the development of field units:

1. In the present design of the chip, the scope observer-plotter sees the following symbol



bright against a dark background. It is quite difficult to have the chip aligned with the direction of the track, since the observer can see nothing that implicitly indicates the direction of the chip.

2. Some of the equipments are somewhat large and bulky for easy transportability.

3. The apparatus is not designed from the viewpoint of serviceability and maintenance.

4. The arrangement of the Mink units requires plotters to stand during operations and results in early fatigue for these men.

5. The design of the Mink units is such that the ambient light in the operations room must be kept low in order not to inhibit the dark adaptation of the plotters.

6. The ultraviolet lights used on the Mink units are unreliable and dissipate too much heat for the comfort of the plotters.

7. The Mink units are constructed with excessive space devoted to support framework and UV lamps.

8. The Rafax does not give optimum integration of signals from noise.

9. It is difficult to indicate courses for preplanned missions on the clear picture screen. These courses were done by scotch-taping teletype tape on the screen.

B. Suggestions for Further Development of the System

1. Automatic Data Transmission. During the course of the tests, the automatic data transmission equipment operated with good reliability and little need for readjustment. While the actual circuit constants employed are more or less arbitrary, there are a number of significant operational features which should be preserved in any future models of the system. The most important of these is the use of digitalized slow-down video information. The actual communication channels employed during the Pope Field tests often had signal-to-noise ratios as poor as two or three to one. It is essential to guarantee the correct passage of information under such minimal operating conditions. The use of a standardized amplitude and shape of video signal greatly simplifies the problem of selecting signals from noise at the decoding end.

The equipments used have been tailored specifically to the AN/TPS-1 radars and AN/TRC communication facilities, carrier loaded with CF-1 carrier bays. The greatest need, in redesign of the equipment for field use, is for proper packaging and for adapting the components for universal application to a variety of radars and communication facilities. This would imply, for instance, that the bandwidth requirements should be tailored to the narrowest bandwidth commonly encountered in military use. The figure of 2,500 cycles used in the present system is realistic but could be reduced.

The various components of the automatic data transmission system are considered below together with recommendations for improvements in these components during the development of a field system.

a. Rafax. The Rafax unit using the P12 storage phosphor proved to be an adequate and reliable integrator for the purpose of the Quick-Fix project. The following features should be incorporated in future models of this gear:

i. The unit should be repackaged to make it smaller, lighter, and more shakeproof. In addition, provision should be made for bringing to the exterior of the unit a number of test points to facilitate servicing the equipment. The present unit is patterned around a 5-inch oscilloscope and a considerable saving in size might be achieved by the use of a 3-inch tube. The mechanical parts of the unit, in particular the motor and optical scanner, could be appreciably reduced in size without loss.

ii. The versatility of the Rafax would be increased by the use of a two-speed scanner drive motor and two sizes of scanning slits to obtain maximum range resolution compatible with the available bandwidth of the communication channel. There are a number of uses for the Rafax integrator aside from its use in an automatic data transmission system. For example, since the digitalized Rafax output presents a clear light-on-dark presentation, it may be useful in local radar installations where a large bandwidth is available between the radar and the PPI consoles. The benefits of integration could be obtained with little loss of azimuth resolution under such circumstances if a fairly fine slit-width and high scanner speed were used.

iii. The Rafax should be provided with a built-in discriminator requiring the addition of only two or three vacuum tubes to the unit, with a choice of standardized or normal output.

iv. A built-in trigger should be provided at zero range on the circular sweep. This feature was added to the Rafax units after they were received from the manufacturer for use during the Pope Field tests. Since the trigger for the remote sweep is derived from the video signal, it is essential that a light spot be present at zero range on the J-scan.

v. The Rafax circuits should be redesigned to obtain better D.C. restoration in the sweep, intensity modulation, and amplifier circuits. One of the deficiencies of the present system is the fact that optimum signal-to-noise integration is not obtained because of fluctuations in the base line of the Rafax output.

vi. The use of additional test equipment would be minimized by inclusion in the Rafax unit of a small 1-inch or 2-inch A-scope to be used for monitoring and testing.

vii. The Rafax should be provided with automatic gain control in the intensity modulation circuits to make the light level on the storage phosphor roughly independent of the RF gain setting of the radar. This feature might be accomplished by biasing the video amplifier gain on the average value of noise signals occurring in the last fifty miles of the preceeding sweep, to eliminate effects of clutter.

viii. Provision should be made for optional transmission of range marks from the LWRU to facilitate alignment of the Mink unit.

b. Encoder. Only slight modifications should be required in the encoder. The actual bandwidth limitations proved to be different from those originally assumed in the first design. The low frequency cutoff of various signals should be above 200 cps. The entire unit should be shielded to avoid radar pickup and built with proper test points to facilitate servicing. The various components of the system are considered separately below:

i. Azimuth Encoding Equipment:

(a) The size of this equipment could be reduced considerably by using a smaller amplifier than the Plan 12 servo amplifier, or the azimuth rate signal might be derived by direct mechanical coupling to the radar antenna.

(b) The equipment should be redesigned to permit following a wider range of antenna scan rates. The present equipment was designed to operate at antenna scan rates of 3 1/2 r.p.m. ± 25 per cent for windage. While this is a reasonable figure for a search radar, it does not cover the entire range which might be encountered in a wider class of field systems. The use of a 60 cycle synchronous motor at the decoder to reconstruct the PPI seems to require a decoded azimuth rate frequency of the order of 60 cycles for best operation of the motor. If this feature is included in the field system, it may be advisable to include an adjustable gear shift at the encoder and decoder to permit a wider range of scan rates without appreciable change of the actual azimuth rate frequency. This problem should be investigated.

(c) The azimuth rate signal should be transmitted on a sub-carrier at about 2,500 cycles rather than sent as a double or quadruple frequency near the low frequency end of the channel. This change would effectively make the transmission of this true frequency independent of the channel on which it is carried. Since the PPI picture is reconstructed using a synchronous motor whose rotation rate is determined by a true frequency, a transmitted reference frequency is required. In the present system, the reference frequency is zero so that only Channel Number 1 is easily adaptable for the automatic data transmission. The inclusion of a modulator to place the azimuth rate signal near the high frequency end of the band would not greatly increase the complexity of the equipments.

ii. The encoding equipment must be built to be compatible with available IFF gear. This feature was not tested because of a lack of IFF interrogators. If the resolution of the Rafax is not sufficient to transmit the characteristic IFF return with proper resolution to permit identification, the Rafax and encoder must be provided with a coincidence circuit to produce a characteristically shaped pulse from a proper IFF response.

C. Decoder

The following changes should be incorporated in field models of the decoder:

i. The size should be reduced by use of a smaller synchronous motor and magnetic clutch. This would reduce the size of the power amplifier required to drive the motor.

ii. It is desirable to modify Plan 12 PPI consoles to permit the presentation of slowed-down video and azimuth information as well as normal video.

iii. The electronic components of the decoder should be mounted near the cathode ray tube of the optical target position indicator to minimize length of leads required between the units.

iv. It may be desirable to provide a standard servo-operated deflection yoke for the Mink unit to operate either from synchronous motor or antenna driven selsyn inputs.

2. Optical Target Position Indicator ("Mink")

a. Operational Features

i. The use of a four-color chip in the display increases the ease in track handling under high traffic density conditions. The use of only one shape of numbered chips simplifies the appearance of the picture from the viewpoint of the controller.

ii. The choice of mirror arrangements which enable the plotting surface, as viewed by the plotter, to appear in the same geometrical aspect as his view of the projection screen proved to be a considerable aid in the conduct of hand-over and identification operations.

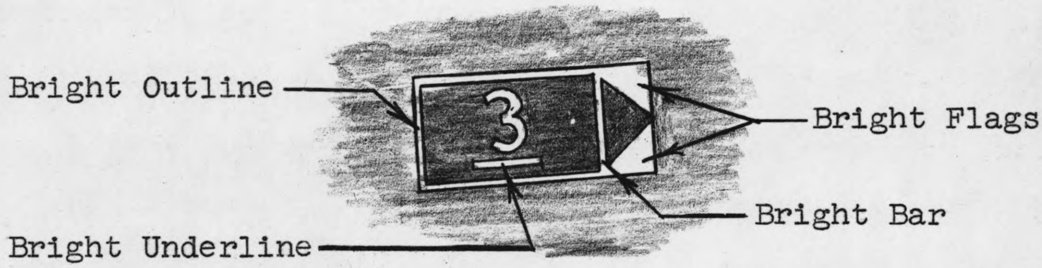
iii. Plotters' efficiency is high because of the basic simplicity of their tasks. These should not be complicated further.

iv. A sufficient amount of dark adaptation is necessary for the plotters to observe the trails of the radar echoes on the P-19 phosphor.

b. Suggested Improvements. The following list of suggested improvements to the optical target position indicator should be considered in the design of the field apparatus:

i. Plotting Chips

(a) To make it easier to align the chip with the direction of the track, the marking on the chip should perhaps look to the plotter as follows:



The bright outline indicates the direction of the chip by two parallel bars which can bracket the trail on the P19 screen.

(b) The triangular region defined by the bar and flags is used to position the chip more accurately on the latest reported position of the target.

(c) The underline simplifies reading inverted numbers.

(d) The chips should be made as simply as possible to permit easy fabrication. They should have molded-in feet and recessed numbers to avoid scraping of the numbers and arrow markings on the plotting surface.

(e) The size of the chips can perhaps be reduced without impairing handling facility. The present chip size of 1/4" by 1/2" does not permit close packing of the chips in regions of high traffic density. The size should probably not be reduced below 3/16" x 3/8".

(f) It may be advantageous to use interference filters rather than tinted lacquers to produce true spectral colors in the chip images. This feature might permit the use of tinted glasses by the controllers to form a selective display of one or two classes of tracks.

(g) Two or three each of five classes of unnumbered chips are required at each plotting board. These should contain characteristic markings for (1) crossing tracks, (2) orbit, (3) hand-over, (4) assist, and (5) fade. The first two classes are required to provide a simply picture of each of these commonly occurring situations without requiring a considerable amount of chip manipulation by the plotters. The second two classes are required wherever overlapping radar coverage is realized, to aid transfer of tracks from one plotting board to another, and to take advantage of the redundancy available when a track which fades on one radar is visible to a second. The fifth class is required so that dead reckoning procedures can be employed without change in identity color. The use of a separate chip to indicate faded tracks would also permit use of the blue numbered chip for a fourth category of identification, such as initial target.

ii. Mink Unit

(a) Seats should be provided for the plotters. This will tend to equalize the difference in heights of the operators and eliminate undue fatigue due to prolonged standing in one position. However, the plan area taken up by the plotters must be kept to a minimum consistent with the dimensions of the shelter.

(b) A molded plotting lens of optimum quality should be used. This lens should be permanently sealed to a plate glass plotting surface. Some attention should be paid to reduction of the size of the optical path and provision of a projection lens arrangement of variable magnification. Addition of these features is desirable only if it would not introduce large delays in manufacture.

(c) Consideration should be given to the possibility of using a beam splitter other than a plane partially reflecting mirror, if the size of the unit can thereby be reduced. The possibility of using a smaller PPI tube and magnifiers should not be excluded unless the increase in complexity would slow production of the equipment.

(d) The high pressure mercury vapor UV lamps should be replaced with cooler, more reliable lighting. This could be provided either by small directed incandescent lights or cold cathode ultraviolet lights.

(e) Simple provision should be made for focusing and adjustment of the optics under a variety of geometrical conditions. Once adjusted, the settings should be easily clamped.

(f) As far as possible, the optics should be sealed against dust and moisture.

(g) The scattered background light from each plotting surface should be minimized, possibly by use of anti-reflection coatings.

(h) The unit should be constructed to be as small and light as possible without decreasing the number of plotting positions to fewer than four.

c. Coordinate Projector

i. The grid coordinate projector should be made integral with one of the Mink units, presumably the center unit in any given arrangement. This would prevent motion of the grid relative to the projected clear picture.

ii. A facility should be developed to provide simple and rapid preparation of new grid negatives. This might be effected by a device similar to a movie titler which included a fixed universal georef grid on which appropriate grid letters could be placed either for photographic reproduction or for direct projection.

iii. The polar grid should be projected with a separate projector.

d. Projection Screen

i. The projection screen should be held taut in a rigid frame to avoid disturbance by air currents.

ii. The controller's side of the screen should be covered with clear Lucite so that preplanned courses could be quickly drawn with grease pencil.

HISTORY OF THE QUICK-FIX PROJECT

A. Cognizance of TAC Problems

The Controls Division of the Control Systems Laboratory had taken, in June, 1951, the introductory problem of studying the feasibility of using a high speed digital computer processing radar data to control simultaneously and automatically about 100 separate tactical missions. The missions were preplanned navigational control problems such as photo-reconnaisance, ground strikes, interdiction, etc. It was recognized that this type of problem represented merely part of the general mission of the Tactical Air Force.

The first introduction to the overall problems of the Tactical Air Force came during the Long Horn maneuvers in Texas in the spring of 1952. Two observers from this laboratory, guests of the Communications and Electronics Staff of the Ninth Air Force Advance, had the opportunity of living with operational people for two weeks and seeing the operational problems of the TAC AC& W system.

B. Study Program and Proposal

In June, 1952, the decision was made by some members of the Controls Division of Control Systems Laboratory, on their own initiative, to investigate those techniques and equipments that could be immediately used in improving the Tactical AC& W system. The study program involved visits to a number of agencies and laboratories throughout the country and occupied a period of about six weeks. This phase of the program culminated in Control Systems Laboratory report R-23, which was presented at a conference of various Air Force agencies held at Headquarters, 9th Air Force, Pope Air Force Base, on July 21-22, 1952. The conference concurred generally in the suggested improvements and recommended that the Control Systems Laboratory implement the technical part of the program, with Rome Air Development Center serving as cognizant authority.

C. Implementation of the Quick-Fix Proposals

It originally appeared necessary for this laboratory to request additional funds for the implementation of the program. To this end, a work statement was prepared and procurement started in September, 1952. Before the receipt of a formal task order from ARDC, a new definitive contract for Control Systems Laboratory was completed, permitting use of unexpended funds for the purposes of the Quick-Fix program, so that additional financing by the Air Force was not required. The total amount expended on the program was about $50,000, exclusive of six plan 12 PPI consoles which were provided as GFE by Rome Air Development Center.

In the choice of devices for accomplishing the functions of automatic data transmission, consideration was given to the possible use of Rafax and Vidicon storage devices, and to the digital relay equipment developed by Air Force Cambridge Research Center and Project Lincoln. Both the Rafax and

Vidicon techniques were under study by the Rand Corporation, Santa Monica, California, for use in an ADC system. On the basis of their results, the decision was made to concentrate on the Rafax equipment.

The Rafax apparatus provides integration and bandwidth compression for the radar video signal only. A number of methods for producing and multiplexing the necessary azimuth information were tried, resulting in the transmission of an azimuth rate signal to a synchronous motor together with a cyclic directional synchronizing signal. The multiplexed signal was encoded by means of a simple circuit modified from one suggested by the Rand Corporation. The final design of this circuit was not frozen until the equipments were in the field.

The optical target position indicator (Mink) was designed after it became apparent that the existing photographic plotting devices being evaluated at Project Lincoln and RADC were inappropriate for a Tactical Air Force system. Several models of the Mink unit were tried out during the autumn of 1952, and the design finally frozen at the end of the year. The three units used during the tests were completed early in February, 1953.

The production of the plotting chips for the Mink units involved a number of time-consuming development problems. By January, 1953, satisfactory techniques had been realized, and production was completed early in February.

D. Pope Air Force Base Tests

Before the equipments could be completed, preliminary measurements of the transmission characteristics of the communications equipment were required. Measurements were taken at Pope Air Force Base on equipments of the 728th AC& W Squadron and 3rd Radio Relay Squadron in January, 1953. Characteristics were measured by transmission of sinusoidal and square-wave signals over typical channels, using tape recorders at the receiving ends. The recorded data were examined at Control Systems Laboratory and the encoder and decoder circuits constructed as far as possible to be compatible with the characteristics of the 3rd RR Squadron carrier-loaded AN/TRC-8 link between Pope Air Force Base and Southern Pines, North Carolina. Final equipments used at the 728th AC & W Squadron differed from these, and some degree of field redesign was necessary.

Late in January, 1953, representatives of the C & E section, Headquarters, 9th Air Force, and the 728th AC & W Squadron visited this laboratory to make final arrangements for the forthcoming tests in the way of provision for adequate power and shelter facilities, and to become familiar with the Quick-Fix equipments and program. At this time, arrangements were also made for air transporting the equipment from Urbana to Pope Air Force Base.

The equipment was brought to Pope Air Force Base on February 17, 1953, and installed in a Jamesway shelter adjoining the normal TADC at the 728th AC & W Squadron. A number of problems became apparent during the installation period, and about six weeks were required before the Quick-Fix TADC became operational. Major problems involved the complete redesign of the oil seal for the plotting lens of the Mink unit and the establishment of reliable communications from the LWRU's.

Training of the Quick-Fix crew was begun on April 2, 1953. About five operational days were spent in training and development of plotting techniques.

The official demonstrations of the Quick-Fix system were held during the weeks of April 14 and April 21. During the demonstrations, the numbers of controlled aircraft were increased, and problems of operational interest evaluated. The demonstrations were witnessed by 335 visitors, listed in Appendix V.

TECHNICAL DESCRIPTION OF THE QUICK-FIX EQUIPMENT

A. Automatic Data Transmission Equipment

The function of the automatic data transmission equipment is to provide at the TADC means for the creation of a PPI picture using radar information gathered by a light weight radar unit. The various components are considered separately below.

1. Rafax

The Rafax bandwidth compressor is manufactured by Haller, Raymond and Brown, Inc. at State College, Pennsylvania. The two units used for the Pope Field demonstrations were modified at the request of this laboratory and contain a number of features which were not incorporated in earlier models of this equipment as described in the September, 1952, issue of Electronics. A small number of additional circuit changes were made at Control Systems Laboratory before the equipment was suitable for field use.

The Rafax bandwidth compressor is an electronic, optical system which uses as inputs the synchronizing pulse and video signal from a radar set. The unit will operate with any radar repetition frequency up to about 3,000 pulses per second, and circuits are provided to select operating ranges of 0 to 30, 50, 100, or 150 miles. The equipment is designed for unattended operation and can withstand reasonable power line voltage fluctuations without deterioration of the operating efficiency.

The equipment is constructed around a severely modified DuMont type 303-A ocsillograph. A welded frame holds the case and supports the remainder of the equipment. The entire unit is 39 inches high, 12 inches wide, and 16 inches thick, and weighs 100 pounds.

The process of producing a narrow band video signal, usually referred to as slowed-down-video (SDV), is carried out by intensity modulating the trace of a cathode ray tube having a moderately long persistence phosphor. The persistence of the CRT phosphor is such that echoes received from targets during one radar pulse repetition interval will not decay before the next interval. The phosphor, therefore, acts as a storage or integrating device and is selected to store target information for a period dependent on the time the radar beam illuminates a single target. This interval approximates a 3^{o} sector in the case of AN/TPS-1 radar rotating at approximately four revolutions per minute with a P12 phosphor in the CRT of the Rafax unit.

The Cathode ray tube of the Rafax displays the integrated video in the form of a circular or "J" scan. This information is sampled by a rotating mechanical scanner containing appropriate lenses and slits to transmit the light signal to a photo-multiplier tube, which converts the intensity modulated trace into electrical variations. The speed of the scanner is adjusted to make at least one full scan before any single stored target decays. In the present equipment, the scanner rotates at 450 rpm.

The range resolution of the SDV signal is determined by the width of the scanning slit. In the present equipment, the resolution is about 1 mile in 150. The bandwidth requirements for transmission of the SDV depend on the slit width, scanner rotation speed, and signal to noise ratio of the communications network. With a range resolution of 1/150 and a scanner speed of 480 rpm, information on the presence or absence of targets at a rate of 1,200 per second requires a theoretical bandwidth of 1,200 cycles for a signal to noise ratio of 2.

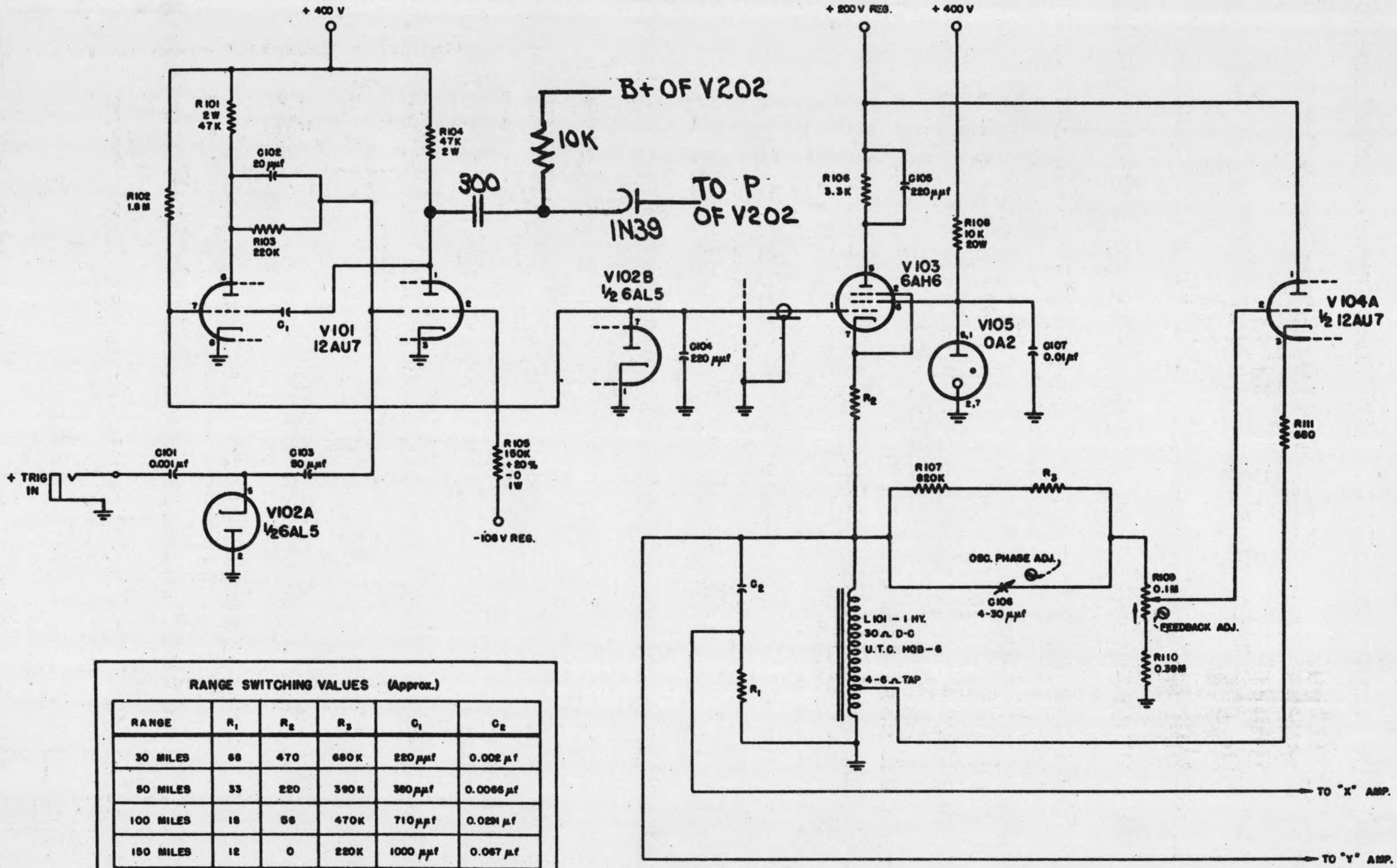
Since a detailed description of the operation of the Rafax unit is given in the maintenance manual for the equipment, the circuit diagrams of the various parts of the apparatus will be presented here without detailed comment except where changes have been made at this laboratory.

Figure 18 shows the triggered circular sweep generator circuits which have been designed to produce a circular trace. A differentiating circuit and diode have been added to produce a bright spot at the beginning of the trace by connecting the components shown between pin 1 of V101 and pin 5 of V202 in the intensity modulation circuit.

The deflection and intensity modulation circuits are shown in Figure 19. The following changes have been made in this circuit:

a. A 200 mmf condenser has been added between pins 6 and 7 of V205 to improve the circularity of the trace.

SECRET



RANGE SWITCHING VALUES (Approx.)

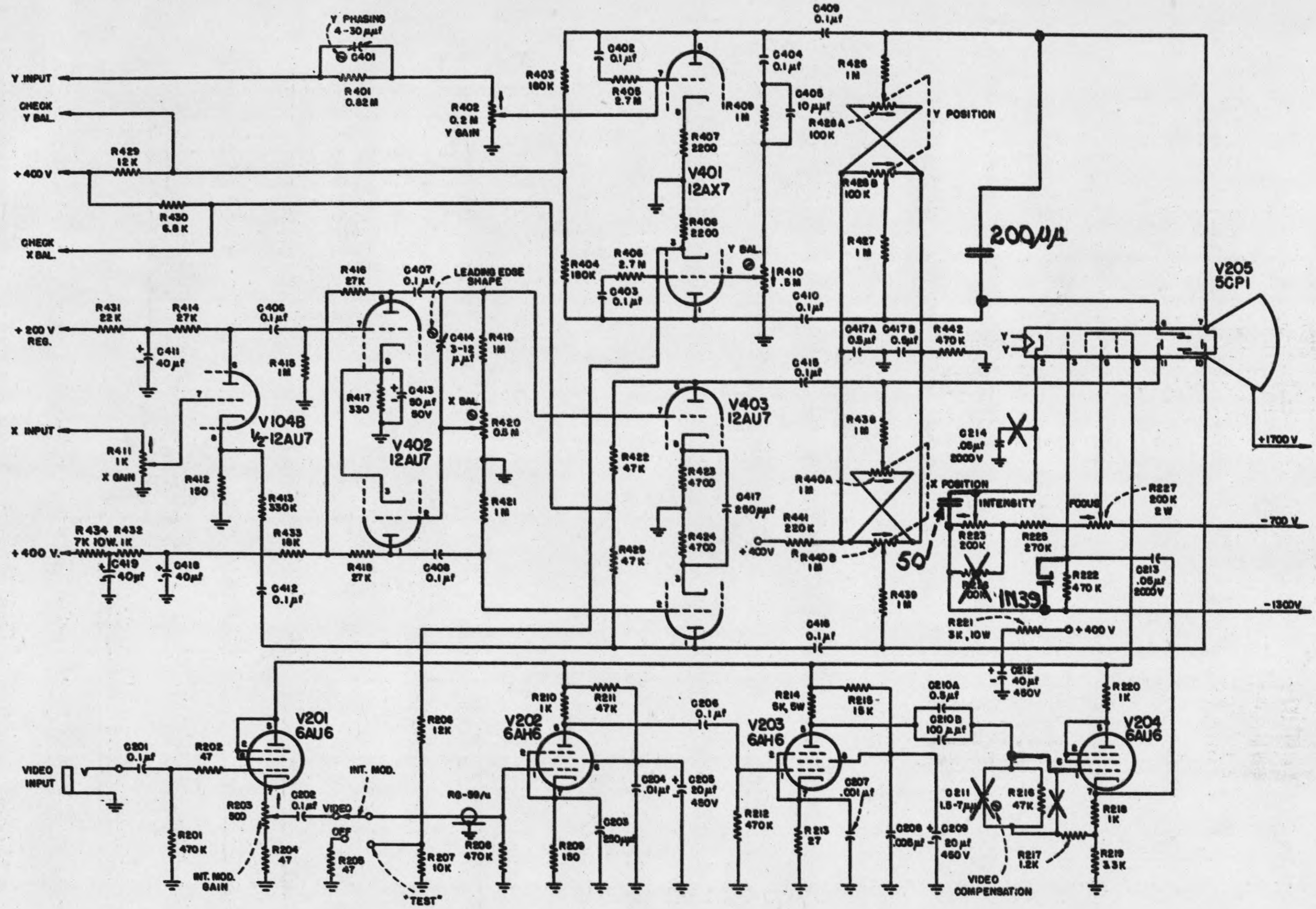
RANGE	R_1	R_2	R_3	C_1	C_2
30 MILES	68	470	680K	220 μμf	0.002 μf
50 MILES	33	220	390K	380 μμf	0.0066 μf
100 MILES	18	56	470K	710 μμf	0.0291 μf
150 MILES	12	0	220K	1000 μμf	0.067 μf

NOTE: UNLESS OTHERWISE SPECIFIED ALL RESISTORS ARE ONE WATT OR SMALLER

Fig. 18 - Circular Sweep Generator Circuits

SECRET

SECRET



NOTE: UNLESS OTHERWISE SPECIFIED ALL RESISTORS ARE ONE WATT OR SMALLER

Fig.19 - Deflection and Intensity Modulation Circuits

SECRET

b. The video compensation circuit has been removed and connection made directly from pin 1 of V204 to the top of resistor R216, to maximize the possible signal available at the cathode of V204. C211 has been eliminated.

c. A 1N39 crystal diode has been added across R222 in the grid of V205 to improve the DC restoration.

d. R226, C214, and a resistor not shown on the diagram which was is series of pin 2 of V205 were removed, and a 50 mf electrolytic condenser added between pin 2 and the -1300 volt supply. These changes were made also to improve the DC restoration.

The power supply and photo-tube circuits are shown in Figure 20. Although not shown on the circuit diagram, a self-contained 2,000 volt power supply, manufactured by Condenser Products Company (Model PS2-2M60A), is installed on the chassis. A small terminal board is mounted on the 2,000 volt terminals with four 1 megohm resistors in series connected as a bleeder across the supply. The positive terminal of the supply is connected to the post-accelerating anode of the CRT, and the center tap of the external bleeder is connected to the normal accelerating anode supply, thus adding an additional 1,000 volts to the total accelerating voltage as required by the P12 phosphor.

2. Azimuth Rate Generator

The function of the azimuth rate generator is to produce a signal whose frequency is a multiple of the rate

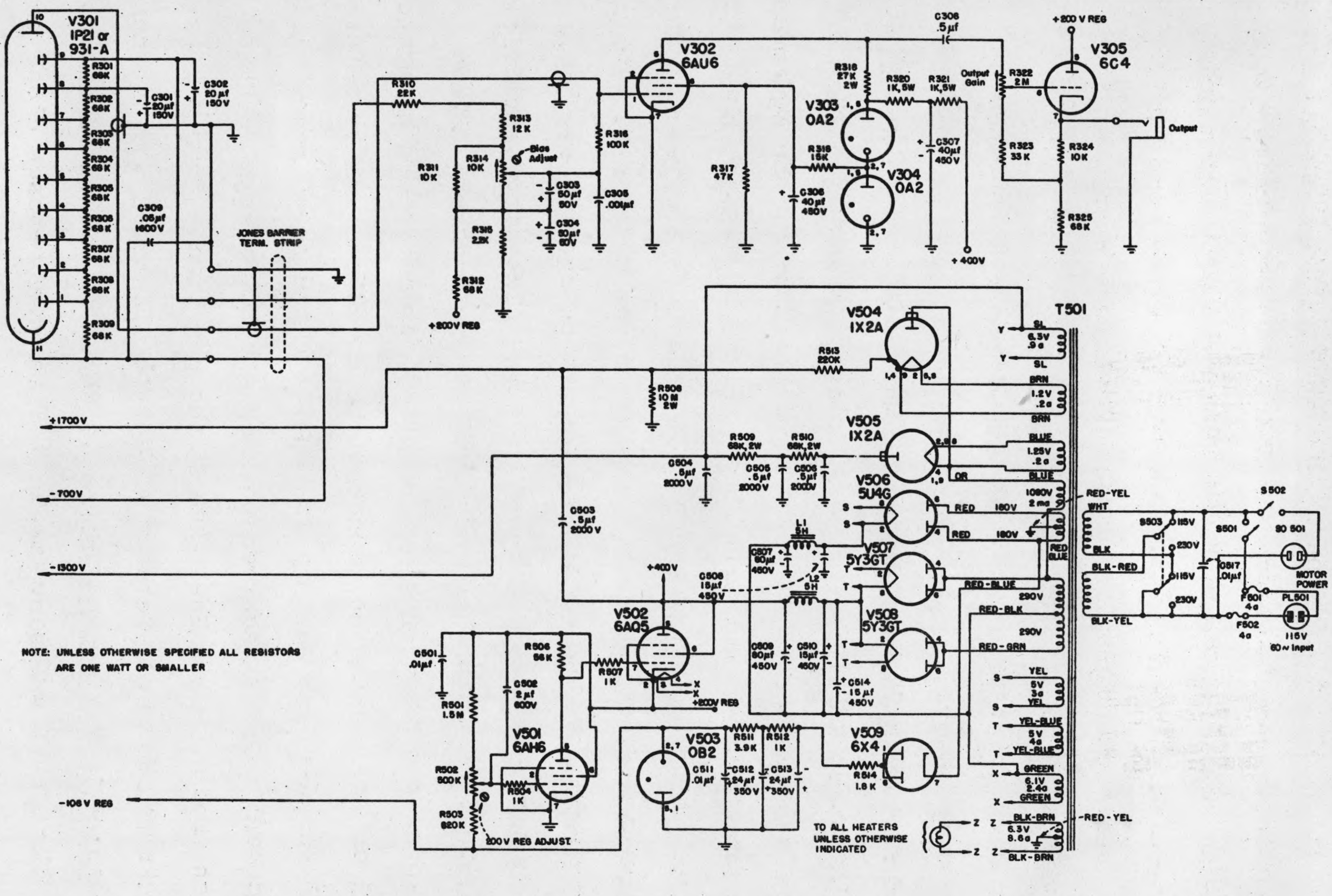


Fig. 20 - Power Supply and Phototube Circuits

of rotation of the antenna of the LWRU. This signal is subsequently used to drive a synchronous motor geared to a rotating coil PPI at the TADC. The equipment must maintain synchronism between the radar antenna and the remote PPI coil when the antenna is subject to windage such that its rotation rate is constant only to $\pm$ 25 per cent. These tolerances are typical of a AN/TPS-1D radar with winds up to 40 or 50 knots.

The azimuth rate generator is designed about a standard plan 12 servo amplifier and PPI rotation assembly. The apparatus is shown in Figure 21. Connection of the equipment is made to the radar through J412 on the AN/TPS-1D, connecting the stator windings of the 1CT selsyn in the gear train to the stator of the 5G 1:1 selsyn in the radar set. Two additional leads are required to bring 60 cycle power from an external generator to the 5G selsyn. The servo amplifier is connected to the same source of 60 cycle power. Since the radar does not contain a remote 36 speed selsyn generator, the unit is operated only on the one speed control transformer.

When the radar antenna is rotating, the servo motor will revolve at a speed required to keep the 1CT selsyn in phase with the 5G at the radar. Using the gear train from a plan 12 indicator, the motor rotates at a rate 432 times the antenna rotation rate. A toothed magnetic wheel is connected directly to the shaft of the servo motor. This wheel passes close to a small magnetic pickup, which in the present case is the

SECRET

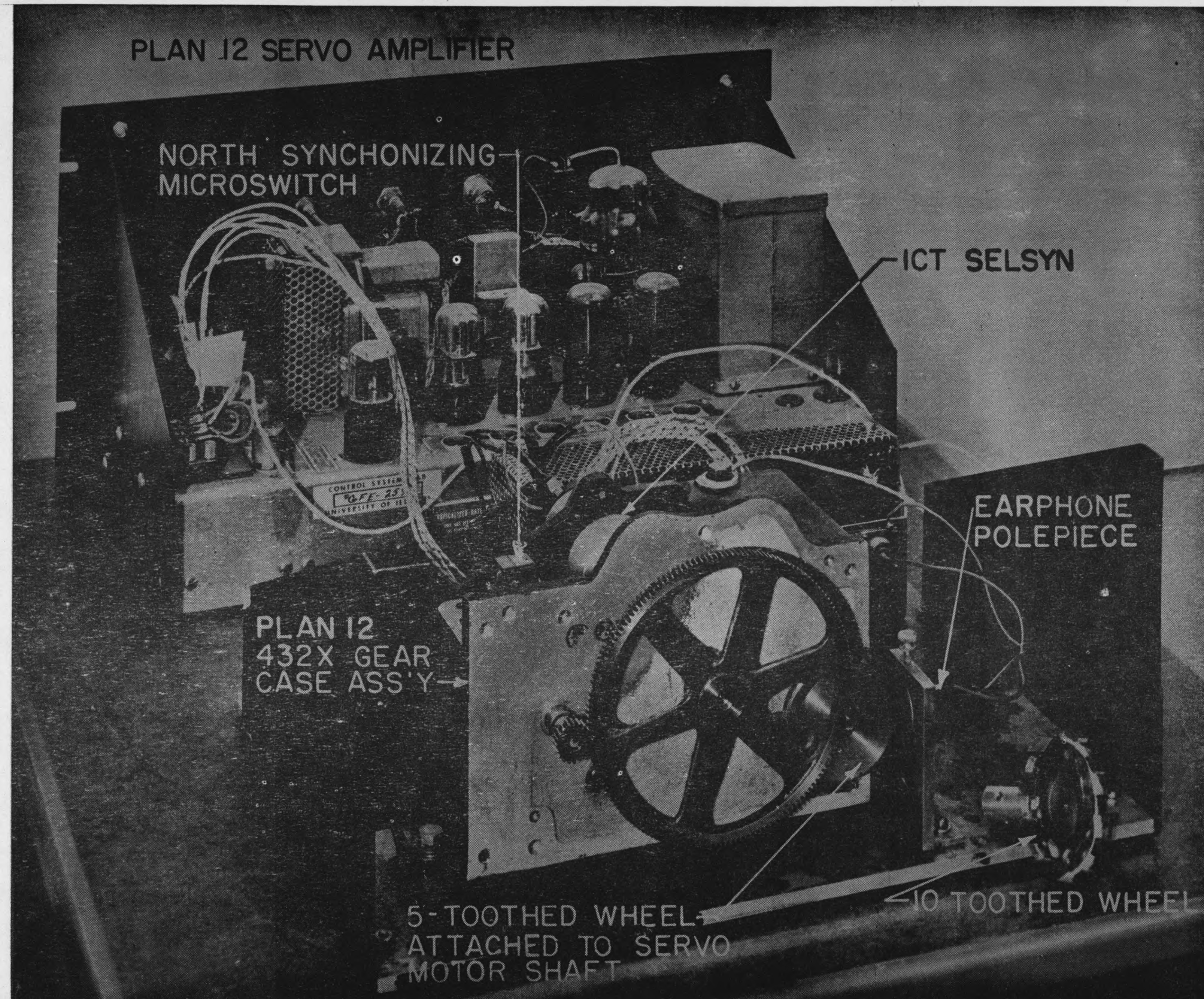


FIG.21 AZIMUTH RATE GENERATOR

SECRET

pole piece of an ordinary earphone. The electrical output of the ear phone is thus a frequency which is 432N times the antenna rate, where N is the number of teeth in the wheel. The value of N is chosen to be compatible with the low frequency cutoff characteristics of the communication facility. In the present installation, N was chosen as 5 for the LWRU site at Laurinburg and 10 for the LWRU site at Goldsboro. This difference was required because of the higher low frequency cutoff of the Goldsboro link, where two intermediate relay stations were involved.

The major difficulty encountered in this unit arose from the variations in the frequency azimuth rate signal produced by hunting of the servo system. This effect has been minimized by constructing the toothed wheel to have a fairly large moment of inertia, and by careful adjustment of the servo amplifier to minimize hunting. A more sophisticated anti-hunt circuit, shown in Figure 22, was designed by Mr. Gooch of this laboratory for use in case the original equipment did not prove suitable in operation.* Hunting is limited in this latter circuit by use of narrow band filters in the servo amplifier circuit. In order to obtain sufficiently narrow bandwidths, the error signal is rectified, then filtered with an RC network, and finally reconverted to the line frequency with a chopper. This alternate servo circuit was not required during the field tests.

* Cf. Control Systems Laboratory Report I-50.

SECRET

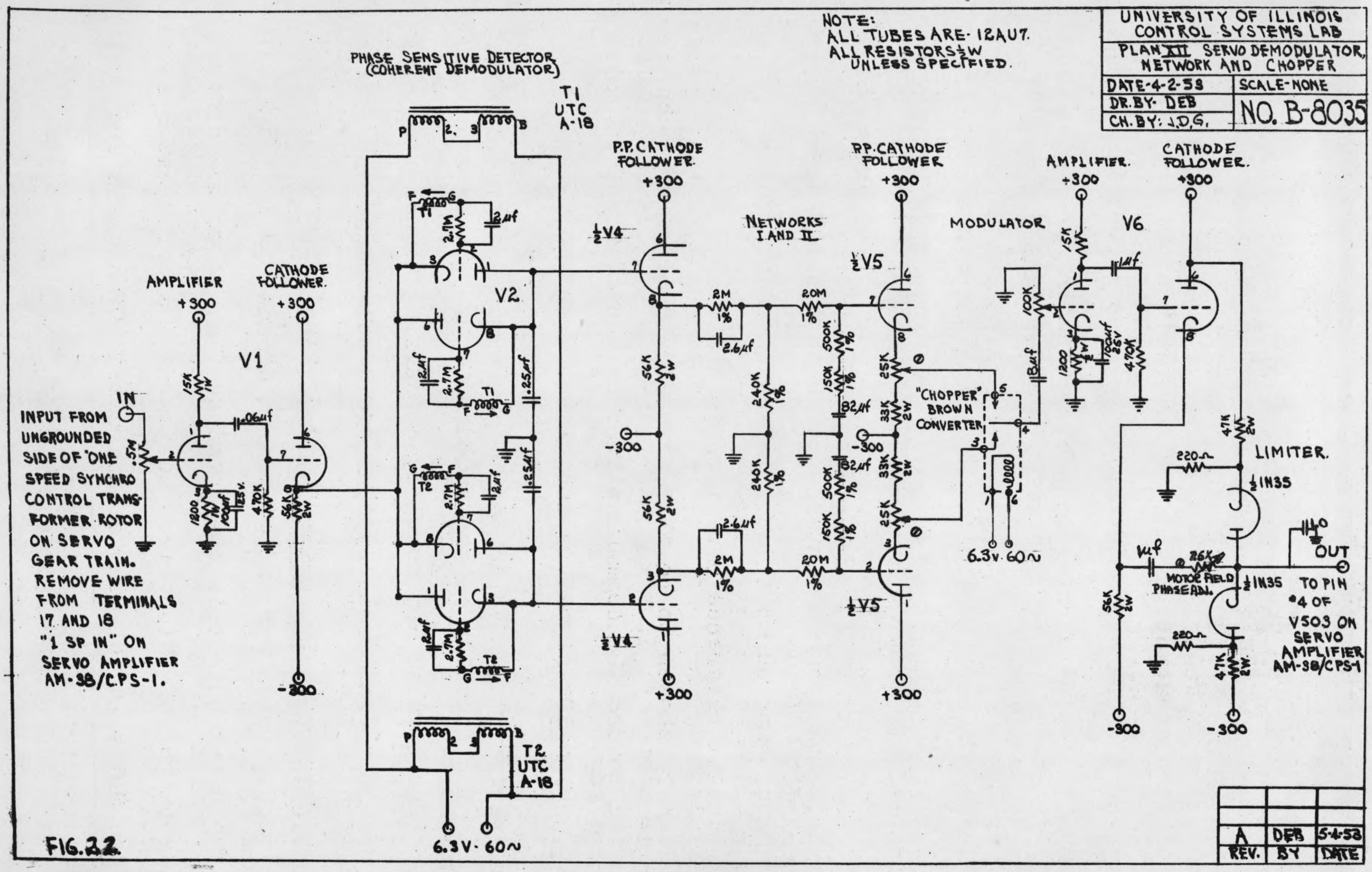


FIG. 22

SECRET

43-85/139
Appendix II

3. North Mark Generator

The function of the north mark generator is to provide a one beamwidth duration synchronizing signal once per revolution of the LWRU. Besides furnishing initial positioning of the remote PPI coil, the north synchronizing signal serves as a check against cumulative errors produced by the azimuth rate generator or by noise or fading in the communications system.

The north mark generator functions through a cam and microswitch attached to the shaft of the 1 speed control transformer on the azimuth rate generator. The switch is closed for 6^{o} when the antenna passes north. Closing of the switch unclamps an oscillator in the encoder. The choice of the fiducial reference direction is arbitrary. The direction is actually chosen to be that at which the radar antenna is pointing toward the communications antennas, since in this position the SDV signal is inhibited.

4. Encoder

The function of the encoder is to provide standardized SDV, azimuth rate, and north synchronizing signals suitable for transmission over a typical field communications system. The circuit is shown in Figure 23. This circuit employs five vacuum tubes and two germanium diodes.

The Rafax output is connected to V1a. A volume control in the output of this triode serves as a discriminator setting for the SDV signals. The standardized SDV signals are

SECRET

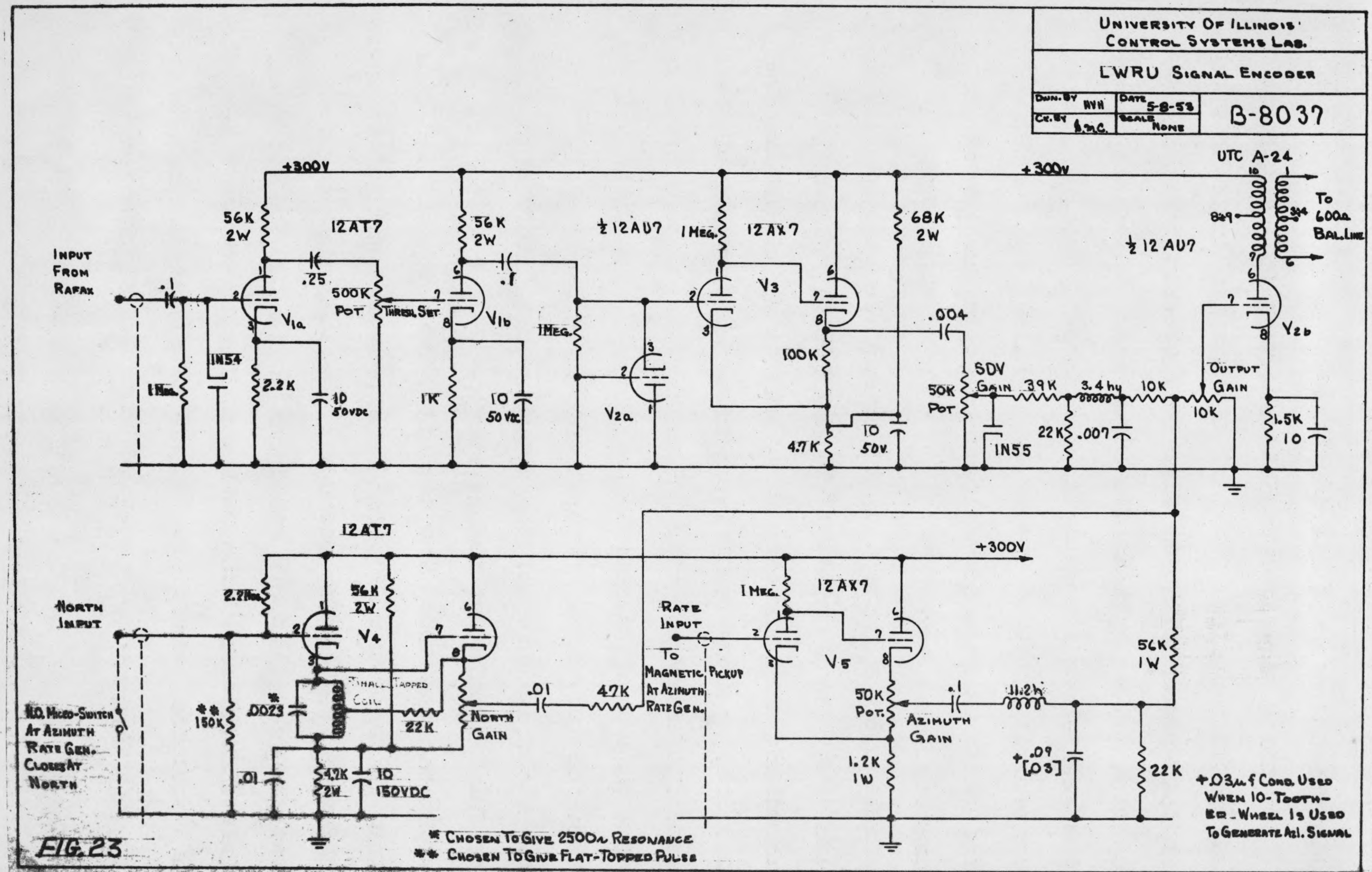


FIG. 23

SECRET

43-87/139
Appendix II

produced by the flip-flop circuit of V3 and the following differentiating and filtering network.

The north mark frequency is produced by the clamped oscillator circuit of V4. The standardized azimuth rate signal is produced by the flip-flop circuit of V5 and the following filter. These two signals are mixed with the SDV signal across the output gain potentiometer in the grid circuit of V2B. The three signals are adjustable by means of three gain potentiometers to be comparable in magnitude.

The combined output signal is derived through a line transformer in the plate of V2B. This signal can be transmitted directly over a 600 ohm balanced line to the carrier bay at the radio transmitter. The output of the encoder is monitored with an ordinary laboratory oscilloscope and a tape recorder.

5. Decoder

The function of the decoder is to provide the necessary signals for reconstruction of a remoted PPI picture at the TADC. The circuit, shown schematically in Figure 24, contains filters for separating the three classes of signals sent by the encoder from each other and from noise, and for properly reshaping these signals for their required functions. The unit contains 13 vacuum tubes and 1 selenium rectifier.

SECRET

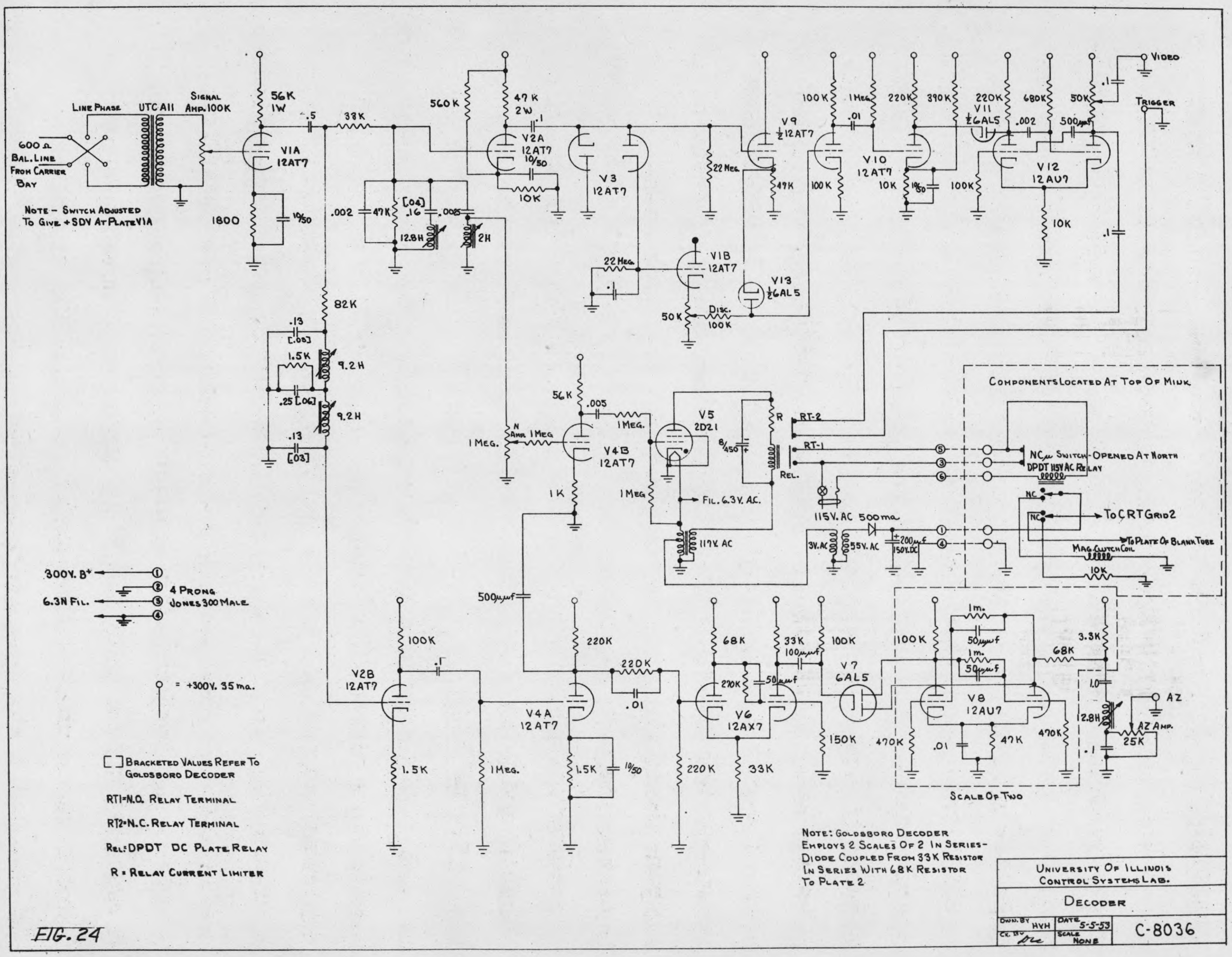


FIG. 24

SECRET

43-89/139
Appendix II

The combined slowed-down video, azimuth rate, and north synchronizing signals are brought from the output of the carrier bay through a line transformer to the grid of V1a. The separation of the three signals is effected at the output of this amplifier stage. The azimuth rate signal is selected by a two section filter and applied to the grid of V2b. The north mark signal is selected by a single section filter and applied to the grid of V4b. The slowed-down video signal is applied to the grid of V2a, the azimuth rate and north mark signals having been removed by single section wave traps. An additional RC trap is introduced at this point to eliminate from the SDV various high frequencies such as local radar interference which may have been introduced during transmission.

The SDV signal, with the azimuth rate and north signals removed, is amplified by V2a, which is biased about to cutoff. The original SDV signal is predominately unipolar, and the line phase DPDT switch is adjusted to give a predominately positive SDV signal at the plate of V1a. The output of V2a is applied to the cathode follower V9 and to the double peak detector circuit of V3 and V1b. This latter circuit provides a discriminator bias proportional to the actual magnitude of the SDV signal, hence furnishing an AGC action. A portion of the DC voltage developed at the cathode of V1b is subtracted from the SDV signal at the cathode of V9, the difference being applied to the grid of phase inverter V10a. Final pulse shaping of the SDV signal is accomplished by amplifier V10b and multivibrator V12. The output video and trigger signals from V12 are passed to a modified Plan 12 indicator circuit which is discussed below. The trigger signal taken from the second plate of V12 passes through normally closed terminal RT2 on a relay which is part of the north mark synchronizing circuit. Since the relay closes when the north synchronizing signal is present, the tube is effectively blanked during this interval and an excessively bright streak is not displayed.

The north synchronizing signal is amplified by V4b and applied to the grid of thyratron V5. AC plate voltage is supplied for V5 through a 6.3 volt filament transformer run in reverse from the AC filament supply. The thyratron is normally biased beyond cutoff by an AC voltage applied to the grid from one side of the heater supply. The plate relay is a DPDT DC relay of about 10,000 ohms resistance.

The center tap of the 6.3 volt transformer supplying the AC voltage for the plate of V5 is brought to the top of another 6.3 volt transformer, run in reverse to supply 55 volts AC to a selenium rectifier and filter. The output of this supply generates a DC voltage for energizing the magnetic clutch located at the top of the Mink unit.

The presence of the north synchronizing pulse causes V5 to fire and closes the plate relay, thereby opening terminals RT2 and closing terminals RT1. Closing of terminals RT1 activates the AC relay at the top of the Mink unit, thereby closing the magnetic clutch and unblanking the CRT. The situation is maintained by the normally closed micro-switch once the antenna coil has been driven past its north position. In normal operation, the north synchronizing pulse will occur at the same instant that the micro-switch opens when the coil has returned to its fiducial position, and the rotation of the PPI coil will continue uninterrupted since RT1 will be closed across the open micro-switch terminals.

The azimuth rate signal is amplified in V2b and V4a and applied to the grid of the flip-flop V6. A condenser is placed between the plate of V4a and ground to eliminate high frequency pick-up, particularly in the form of interference from local radars, which can trigger the flip-flop of V6. The differentiated output of the flip-flop is applied to scaler V8 through diode V7. The number of stages of scales of two employed is a function of the incoming azimuth rate frequency. In the present equipments, a single scale of two was used when a five-toothed azimuth rate wheel was employed at the encoder, and two scales of two in series used where a ten-toothed azimuth rate wheel was required. The output of the scalers is filtered and applied to a power amplifier which is used to run the synchronous motor driving the PPI coil. The azimuth amplitude setting is adjusted so that the output of the power amplifier is about 115 volts AC. The power amplifier and associated power supply are shown in Figures 25 and 26.

6. Modified Plan 12 Indicator Chassis

A number of changes are required in the conventional Plan 12 indicator chassis to permit use of this circuit with SDV signals. The modifications are indicated in Figure 27, with the circled components being those which have been changed for this purpose. The only changes required are for provision of a longer sweep gate in the sweep multivibrator circuit, and for increased time constants in the succeeding RC coupling networks. The 0.1 microfarad condenser, C312a, normally used in this circuit between Pin 2 of V305 and V306 was an oil-filled bathtub type condenser. This condenser gave excessive leakage current in R345 and was replaced with a paper 0.1 mf condenser.

The normal off-centering circuit was used to drive the high resistance focusing coil on the CRT. The Plan 12 focus coil was replaced with an equivalent resistor.

7. Deflection Assembly

The deflection assembly is located at the top of the Mink unit and comprises the drive motor, focus coil, deflection coil, etc.

The two units which operate on SDV from the LWRU sites use different deflection assemblies from that employed for the local radar. This requirement is dictated

SECRET

UNIVERSITY OF ILLINOIS
CONTROL SYSTEMS LAB

POWER AMPLIFIER FOR YOKE MOTOR

DATE 5-11-53	SCALE = NONE
DR BY JL	NO. A-8038
CH BY G.M.C.	

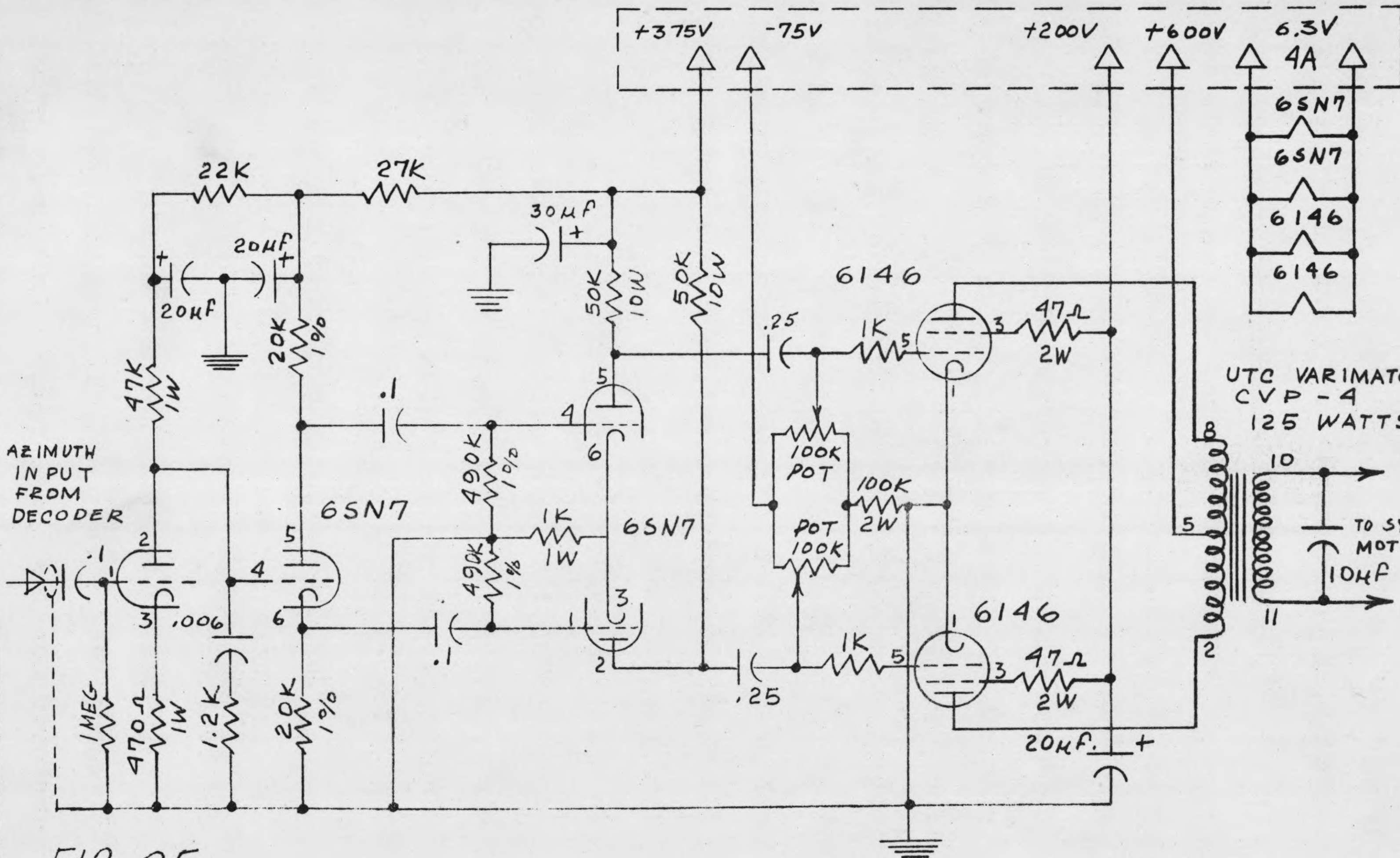


FIG. 25

SECRET

SECRET

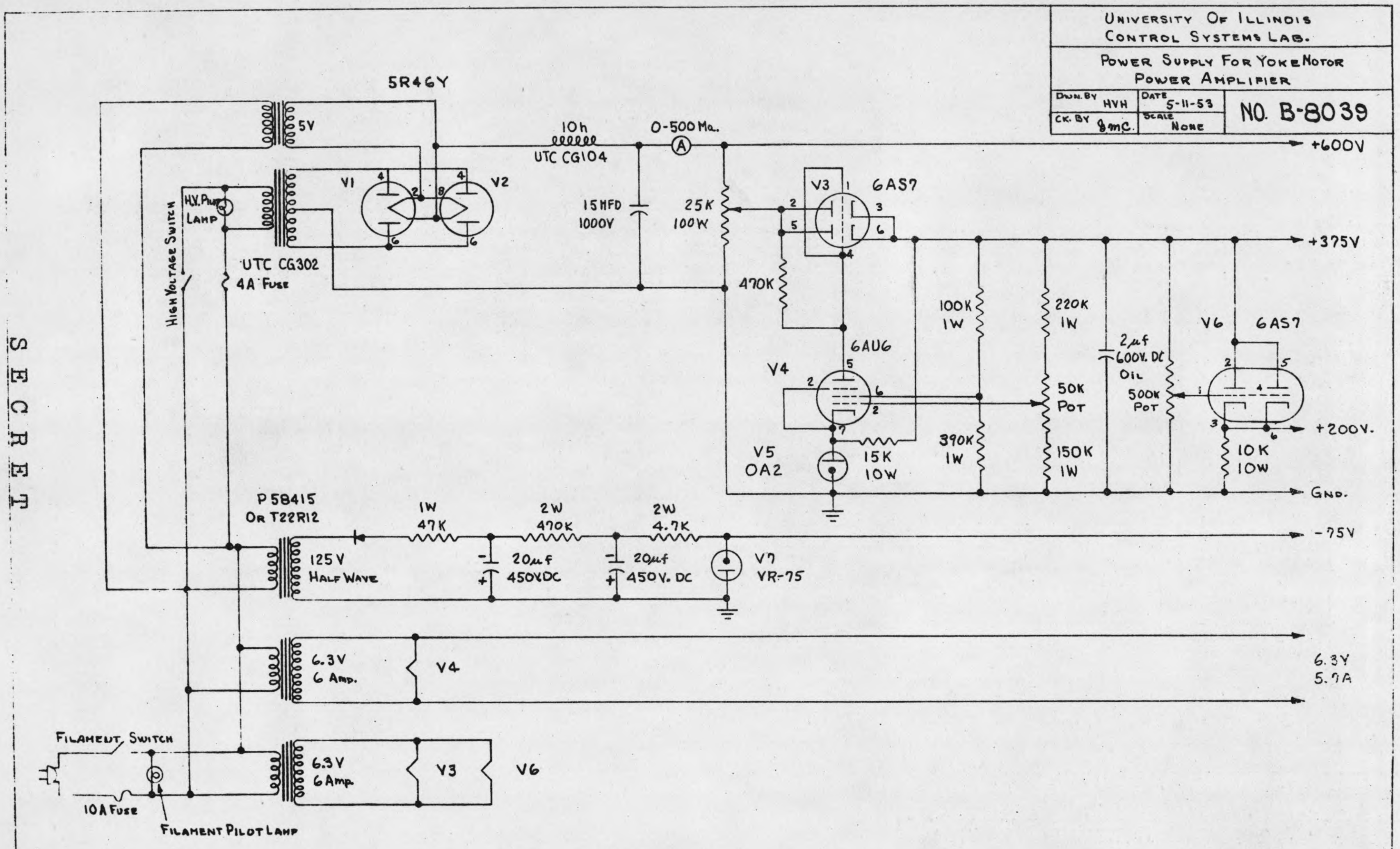


FIG. 26

SECRET

43-95/139
Appendix II

SECRET

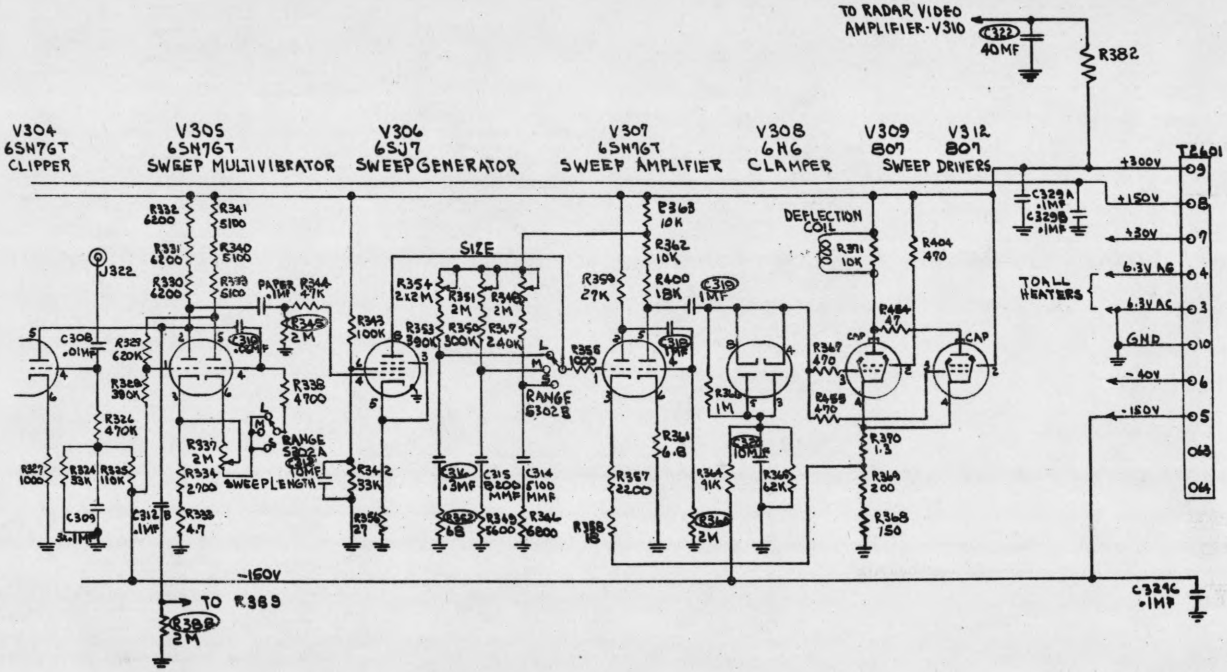


FIG.27 MODIFIED PLAN 12 INDICATOR CHASSIS.

SECRET

by the necessity of driving these yokes with synchronous motors rather than servo motors. The LWRU Mink deflection assemblies are built around a basic Raytheon Pathfinder radar gear case assembly. This assembly is shown in Figure 28. The synchronous motor employed is an EAD LH73ACJ-1, which, with a rating of 1/100 hp, is larger than actually required. The gear train between the motor and deflection coil effects a reduction of 540:1. The magnetic clutch, cam, and micro-switch shown are used to achieve the north synchronization. The deflection coil actually employed is an EDO-000565 yoke made by DX Radio Company, Chicago, obtained when the original Raytheon coil was found to be unsuitable. The focus coil is a Raytheon FC-234, 8300 ohm resistance, provided with the gear case assembly.

The deflection assembly for the center Mink unit, which operates from the local radar, is constructed from a standard Plan 12 gear case assembly, with the substitution of the above focusing and deflection coils for the ordinary Plan 12 components. In addition, some metal parts have been removed in the vicinity of the deflection coil to eliminate the open-centered sweep which arises from eddy currents flowing near the coil. A simple Lucite ring was machined to hold the deflection coil in place in the front end of this assembly. This center unit is operated from an unmodified Plan 12 indicator chasis and a standard Plan 12 servo system, using the two speed selsyn system available at the AN/CPS-5.

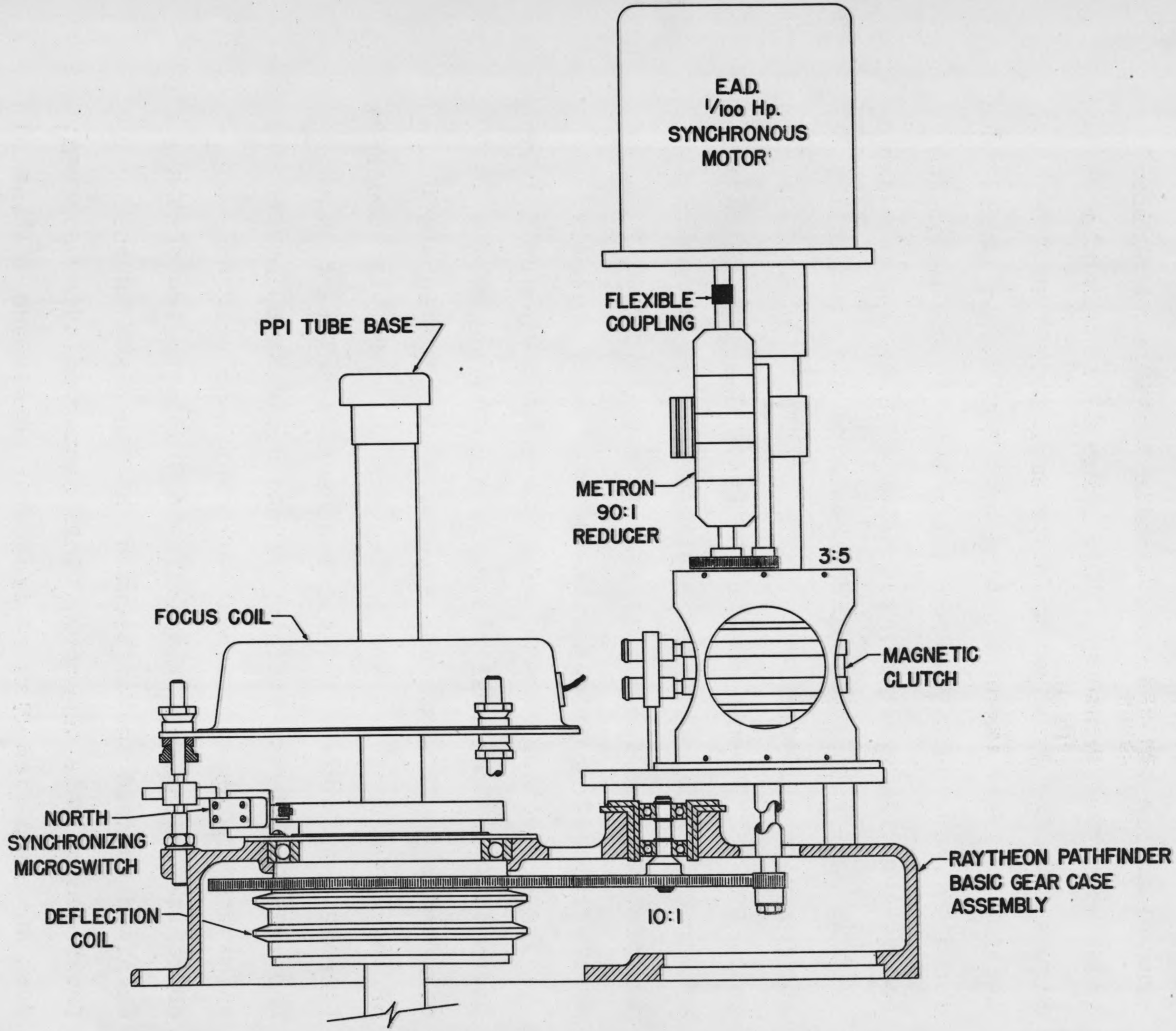


FIG. 28 DEFLECTION AND DRIVE ASSEMBLY FOR LWRU MINK UNIT

SECRET

8. Power Supply

A standard Plan 12 power supply is used to furnish operating voltages for the decoder and modified indicator chassis. For operation of the 16-inch cathode ray tube with P19 screen, a high voltage supply of the order of 18kv DC is required. In the present equipment, this is furnished by a Norelco RF power supply taken from a projection television system, which is placed in the Plan 12 power chassis in the space normally occupied by the 6kv high voltage supply. The supply is nominally rated at 25kv, but the output has been limited to 18kv by insertion of a series resistance to drop the B supply voltage to the Norelco supply.

9. Communications Equipment

The communications equipment used during the Pope Field tests was standard field gear furnished by the 728th AC & W Squadron and the 8th Communications Group. Both AN/TRC-1 and AN/TRC-8 transmissions equipment was employed, together with CF1-A carrier bays at the terminals.

The 38 mile distance between Pope Field and Laurinburg was covered by a single AN/TRC-1 link with AN/TRA-1 amplifiers at both ends. The transmission between Pope Field and Goldsboro was effected by use of AN/TRC-8 equipment between the TADC and Vaughan Hill at Fort Bragg, followed by AN/TRC-1 with AN/TRA-1 from Vaughan Hill to Bentonsville, North Carolina, which was located about twenty miles from Goldsboro at the edge of the high part of the coastal plateau. AN/TRC-1 equipment was used for the final transmission to Goldsboro from Bentonsville.

The major difficulty encountered in installation of the communications system arose from lack of accurate topographical maps of the area. For this reason, it was only possible to obtain reliable line-of-sight communications by trial and error. For the purposes of the demonstration, it was felt necessary to obtain a high degree of reliability to insure that visitors would have an opportunity to inspect the site in operation. Satisfactory operation of the automatic data transmission equipment was realized under transmission conditions where the signal-to-noise ratio was of the order of 2:1 or better. This condition is represented by a circuit of fair to poor voice quality.

B. Optical Target Position Indicator ("Mink")

The function of the optical target position indicator is to provide a simple mechanism for derivation of a clear picture of the air situation from a radar PPI picture. The raw PPI picture may be derived either from a local radar or from a remote LWRU by techniques described previously. The Mink unit is shown in Figure 29.

1. Cathode Ray Tube

The cathode ray tube employed with the Mink unit is a flat-faced sixteen-inch diameter tube furnished with a P19 long persistence phosphor. The tube has magnetic focusing and

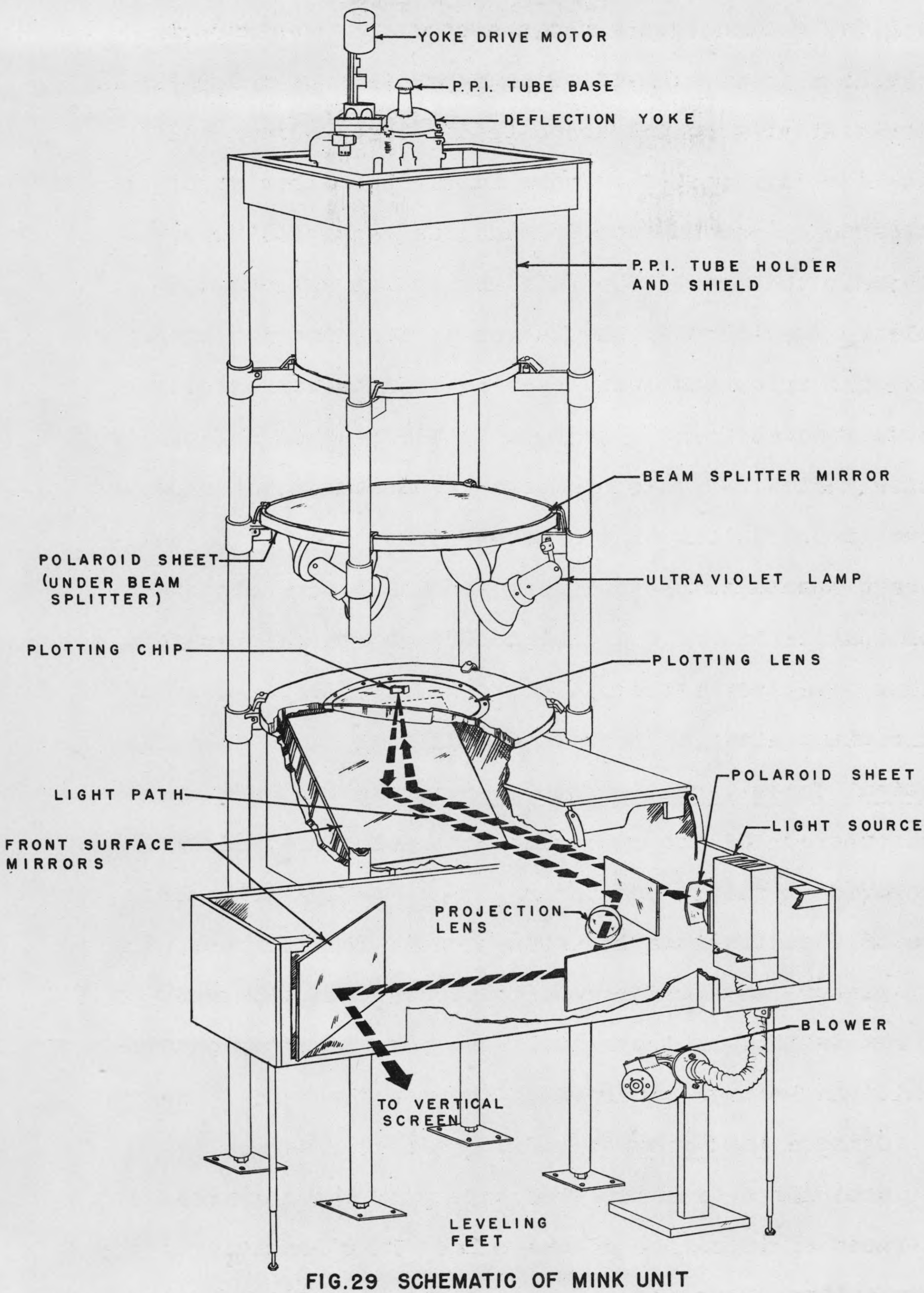


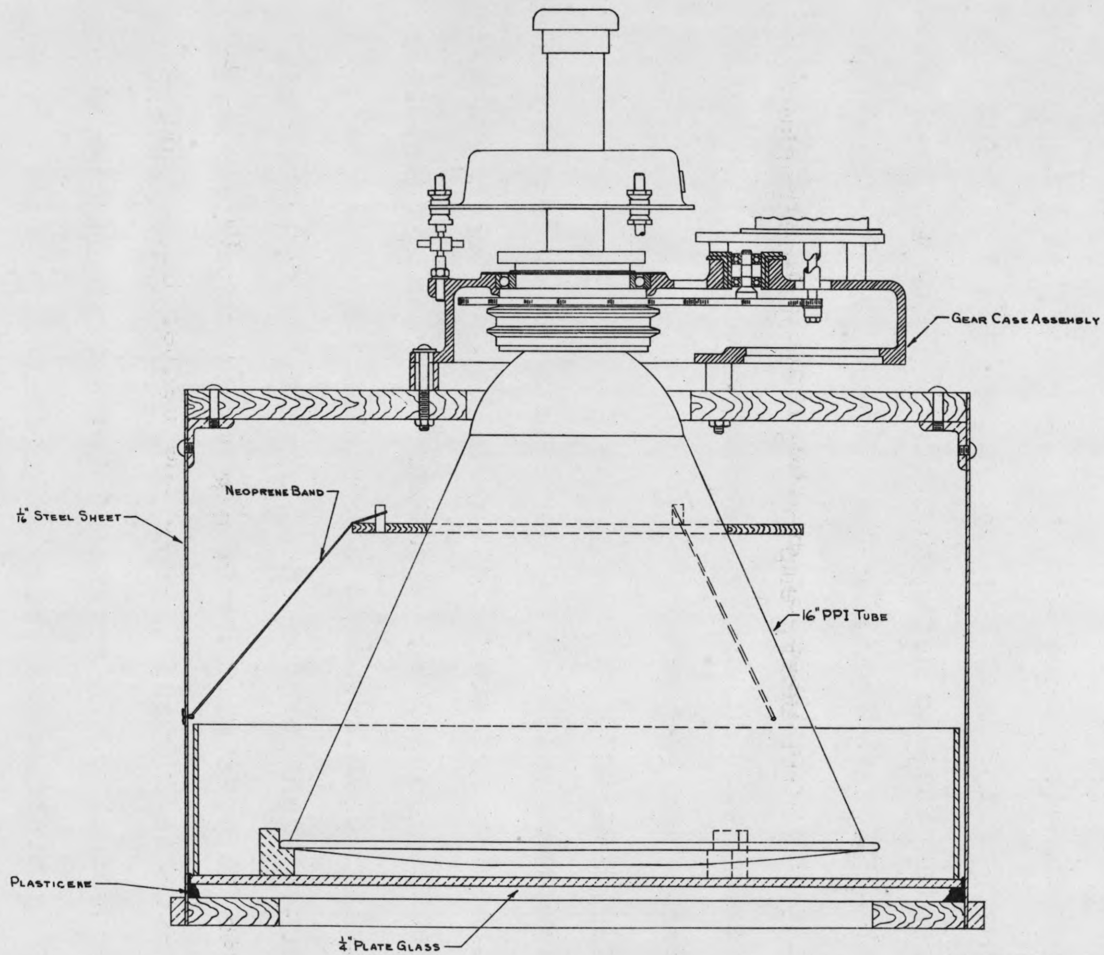
FIG.29 SCHEMATIC OF MINK UNIT

magnetic deflection, and employs a straight electron gun. The tube face is aluminized after deposition of the phosphor to inhibit flaking of the magnesium fluoride screen and to optimize the light output of the tube. The tubes were manufactured by the Rauland Company, Chicago, Illinois.

The main feature of the PPI tube is the extreme long persistence furnished by the magnesium fluoride phosphor. With strong excitation, the trail is clearly visible for about two minutes. The observer-plotter is thus able to determine rapidly whether or not a given radar echo is to be associated with a moving or stationary target, and the trail furnishes a simple facility for his determining the speed and direction of the target. The image as viewed on the P19 screen, since the phosphor is single layered, occurs without a bright flash. In addition, this phosphor has a large dynamic range of light output which more than compensates for the extended storage characteristics in the face of ECM.

The PPI tube is mounted at the top of the Mink unit inside a metal can which serves to support the tube and deflection assembly and to shield the operating personnel from the high voltage required to operate the tube. The bottom of the shield consists of a sheet of 1/4-inch safety plate glass to insure the safety of the operators in the event of implosion of the tube. This assembly is shown in Figure 30.

SECRET



REV.	BY	DATE	UNIVERSITY OF ILLINOIS CONTROL SYSTEMS LABORATORY	
			Tube Mounting And Enclosure	
			DATE June 19, 1953	SCALE Half Size
			DRAWN BY V. Hampton	No. C-8041
			CHECKED BY	

FIG. 30

SECRET

43-103/139
Appendix II

2. Beam Splitter

The beam splitter used in the Mink unit is a partially reflecting mirror of 28-inch diameter obtained from Evaporated Metal Films, Inc., Ithaca, New York. The mirror is aluminized to reflect 80 per cent and transmit 20 per cent. The beam splitter is located below and parallel to the PPI tube face. The position of the beam splitter is arranged to fall slightly below the line of sight of the observer and midway between the PPI tube face and the top of the plotting lens. A circle of 18-inch diameter at the center of the beam splitter is opaqued at the bottom to prevent direct light from falling onto the PPI tube.

3. Plotting Lens

The beam splitter is arranged so that the virtual image of the face of the PPI tube falls on the flat surface of the plotting lens. The plotting lens has a focal length of 50 inches and an aspheric correction. The top flat surface of the lens is formed by a sheet of 1/4-inch plate glass which is optically sealed to the plastic lens with a simple mineral oil seal, employing a neoprene gasket and compression ring. This arrangement is shown in Figure 31. The use of a mineral oil seal was dictated by lack of proper equipment for sealing glass to plastic. Since sufficient time was not available to make molds, the lenses were prepared by machining from 2-inch thick Lucite sheet.

SECRET

REV.	BY	DATE	UNIVERSITY OF ILLINOIS CONTROL SYSTEMS LABORATORY	
			ASSEMBLY OF PLOTTING TABLE	
			DATE JUNE 22, 1953	SCALE HALF SIZE
			DRAWN BY V. HAMPTON	No. B-8042
			CHECKED BY	

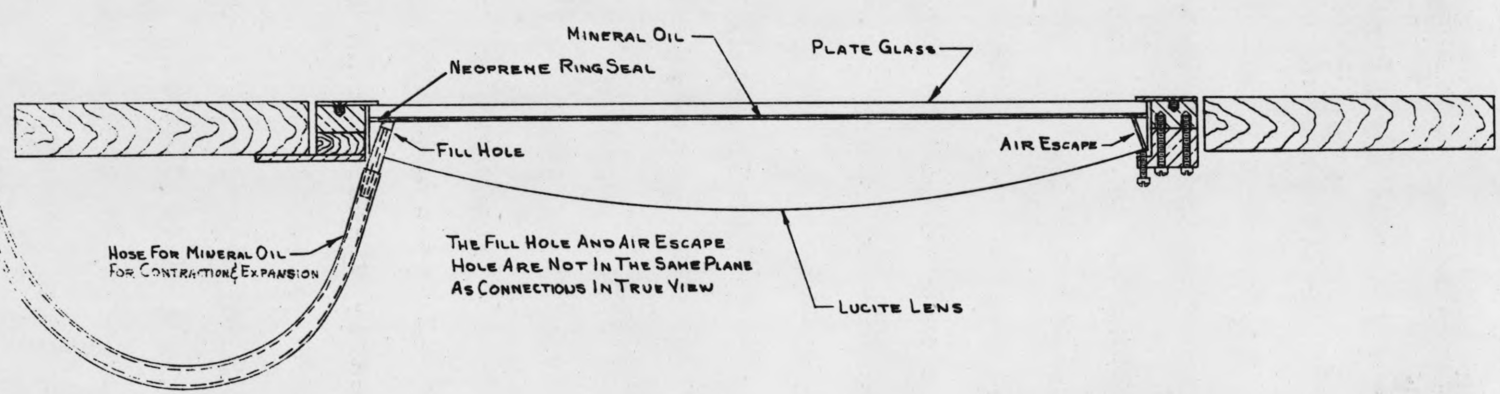


FIG. 31

SECRET

43-105/139
Appendix II

The lenses were rough cut using a simple jig and were ground and polished with a lap using fine pumice, rottenstone, emery, coarse rouge, and silver polish as abrasives.

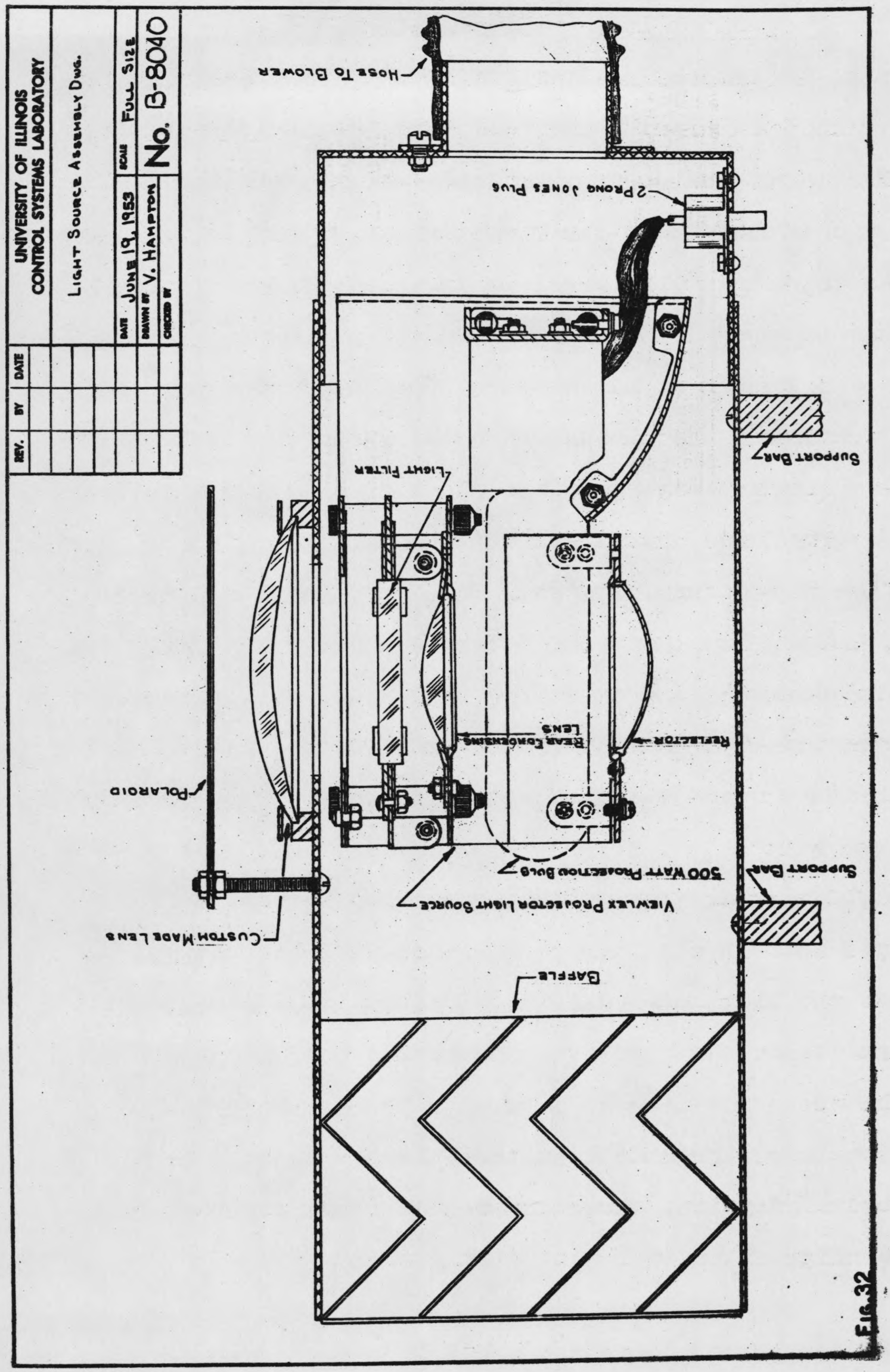
Machining the lens in this manner proved a tedious operation. Because of limitations on the size of the lathe available, a special vacuum chuck had to be built to hold the Lucite sheet in position during machining. The final surface of the plotting lens was considerably rougher than that obtainable by proper molding.

4. Light Source

The light source employed in the Mink unit is modified from a projection assembly obtained from Viewlex, Inc., Long Island City, New York. A louvered hood and cooling assembly have been added and the original front condenser lens supplied with the unit replaced by a 5.5 diopter 90 mm diameter lens, supplied by Mr. Joseph Schmitt, Madison, Wisconsin. The light source is shown in Figure 32.

A 300 watt to 500 watt standard projection lamp is employed in this unit and provides sufficient illumination to make the chips clearly visible in an area of moderate ambient light.

The cooling blower is separated from the light source by a length of flexible hose to prevent vibration of the Mink unit. Any such vibration results in unclear images of the chips.


UNIVERSITY OF ILLINOIS
CONTROL SYSTEMS LABORATORY
LIGHT SOURCE ASSEMBLY DWG.
REV. BY DATE
DATE JUNE 19, 1953
DRAWN BY V. HAMPTON
CHECKED BY
SCALE FULL SIZE
No. B-8040
HOSE TO BLOWER
2 PRONG JONES PLUG
SUPPORT BAR
LIGHT FILTER
REAR CONDENSING LENS
REFLECTOR
POLAROID
500 WATT PROJECTION BULB
VIEWLEX PROJECTOR LIGHT SOURCE
SUPPORT BAR
CUSTOM MADE LENS
BAFFLE
FIG. 32

5. Projection Lens

The projection lens employed in the Mink unit is a 40-inch focal length achromat, anti-reflection coated, obtained from the Jaegers Optical Company, New York. The position of this lens can be varied to obtain proper focusing of the plotting chip images on the projection screen.

6. Mirrors

A number of mirrors are required in the Mink unit for bending of the optical path, as shown in Figure 29, to achieve proper imaging of the plotting chips on the screen. All mirrors used are first surface aluminized mirrors obtained from Jaegers Optical Company, New York, and Evaporated Metal Films, Inc., Ithaca, New York.

The large 45-degree mirror below the plotting surface is inserted to change the optic axis of the system from vertical to horizontal. The other three mirrors are added to give a left-to-right reversal in the horizontal plane so that the rear view of the projection screen, as seen by the observer-plotter, corresponds with his view of the actual plotting surface. This feature is of considerable importance in the hand-over and assist operations during plotting.

The last mirror is adjustable in two axes to permit simple geographical centering of the image for the proper compositing of several Mink displays.

7. Polaroid

A pair of large polaroid sheets (0.007 inch) is placed beneath the beam splitter mirror and can be rotated such that the background of scattered light from the plotting surface and fluorescent light from the chips is compatible with the light intensity on the PPI surface as viewed by the observer. A third polaroid is added in front of the light source, crossed with one of the other polaroids to minimize the background of light scattered by the projection lens and the internal surfaces of the Mink unit.

8. Projection Screen

The projection screen employed during the Pope Field tests was hand-made from vinylite sheets seamed with an iron and then sprayed with white paint. This material provided a translucent screen of adequate quality for the demonstrations. The screen was supported by a frame composed of 1/2-inch steel rods and laboratory clamps. The frame was suspended from a pair of simple, wooden A-frames.

During operations which called for navigation of aircraft over preassigned paths, the control paths were marked with tape on the unpainted side of the screen. Such a track is visible in Figure 7.

9. Grid Projector

A reference grid, giving polar and georef coordinates relative to the center of the radar system is furnished by a standard 6 x 6 centimeter slide projector mounted on the front of the center Mink unit. In order to make the size of the grid compatible with the screen size and available throw distance, a 2.5 diopter 50 mm. diameter spectacle lens was obtained from the Fort Bragg optician and fastened over the normal projector lens.

A variety of reference grids, both polar and georef, was prepared at this laboratory before the tests by photographing appropriate inked drawings. During the operations, only a single reference grid was employed. This grid, which is visible in Figure 7, was a combined polar and georef coordinate system with 30 degrees, 50-mile radii, and major georef lines thicker than the finer divisions. The intensity of the grid lines relative to that of the chips was adjustable by means of a Variac controlling the projector light source. On a number of occasions, attempts were made to improve the clarity of the grid by use of color filters over the projection lens. These attempts were abandoned, since they did not appear to produce any improvement in the clear picture.

The alignment of the Mink units relative to the grid is a straightforward operation. The center Mink and grid projector are first positioned so that projected images of chips placed along the circumference of the observed image of a circle of constant range (provided by the radar range markers) fall on a circle of the polar grid. The sweep length of the Mink PPI is then adjusted so that the observed circle corresponds to the proper grid range. Proper directional orientation of the Mink is then effected by rotation of the PPI control transformers so that the projected image of a chip placed on the observed image of a known landmark falls at the appropriate grid direction. (If only nearby landmarks are visible to the radar, the PPI sweep can be expanded for this step.)

In alignment of the LWRU Mink units, the Mink is first positioned and the final mirror adjusted so that the projected image of a chip placed at the observed image of the PPI center is brought to the proper georef grid position. Directional orientation is achieved by rotating the North synchronizing cam so that the projected image of a chip placed at the end of the observed image of the "North" synchronizing strobe bears the proper grid direction relative to the image of the center chip. Finally, the LWRU Mink PPI sweep length is adjusted so that images of chips placed on a target under surveillance by both the center and LWRU Minks are brought into coincidence. This final adjustment can also be made by reference to range markers transmitted from the LWRU (not available during the present tests).

C. Plotting Chips

The function of the plotting chips has been considered before. The chips were manufactured at this laboratory prior to the Pope Field tests, using part-time student help, at a cost of about $5.00 per chip. The following sequence of operations was employed:

1. Using a hand-fed, water-cooled, high-speed, carborundum cut-off wheel, 0.250-inch polished plate glass was cut into strips about 0.35 inch wide.

2. The blanks were then rough-ground to 1 1/2" by 0.35" strips.

3. The 1 1/2" by 0.35" strips were then cut into 0.25" by 0.35" pieces, and the ends smoothed against a cut-off wheel. The finished blank was 0.500" ± 0.005" by 0.350" ± 0.003".

4. The blanks were optically ground and polished by Mr. Joseph Shmitt, Madison Optical Service, Inc., Madison, Wisconsin.

5. The chips were then aluminized on the four polished faces and hard coated with SiO by Evaporated Metal Films, Inc., Ithaca, New York, at a cost of fifty cents per chip.

6. An aluminum square, .295" by .02" thickness was then fastened to each end of the chip. This square was cemented to the chip with pheno-weld Number 7 cement obtained from H. B. Hardmen and Company, Belleville, New Jersey. A slight under-cure prevented bond stresses in excess of the fracture limit of the glass and inhibited resultant conchoidal fracture under temperature stress.

These aluminum squares are referred to as "feet" since they support the chip and prevent contact between it and the plotting surface. It is necessary that the feet overhang each end of any one face of the chip exactly the same amount, and that the edges be parallel with the face. To insure this condition, a jig was employed for holding an assembly of fifty chips for gluing on the feet. Because of variations in chip thickness and in size of the aluminum feet, only the overhang for two faces per chip could be controlled by spacers.

7. After the cementing, each chip was placed in a holder through which its feet projected, and the feet filed carefully to the overhang allowed by the holder. The chips were then tested by a simple schlieren technique to check whether the planes of the edges of the feet were parallel to the planes of the faces of the chip. This arrangement is shown in Figure 33. With the chips placed on the plate glass at point M, a bright chip will be seen by the observer if the face of the chip is not normal to the optic axis, since the image of the black dot will miss the observer's pinhole. The filing operation was repeated on each face until a good parallel surface was insured.

8. The chip was now lacquered. Each of the four aluminized faces received a different color. The major problems involved were to obtain smoothness and clarity of the lacquer coat, uniform optical density and color, without

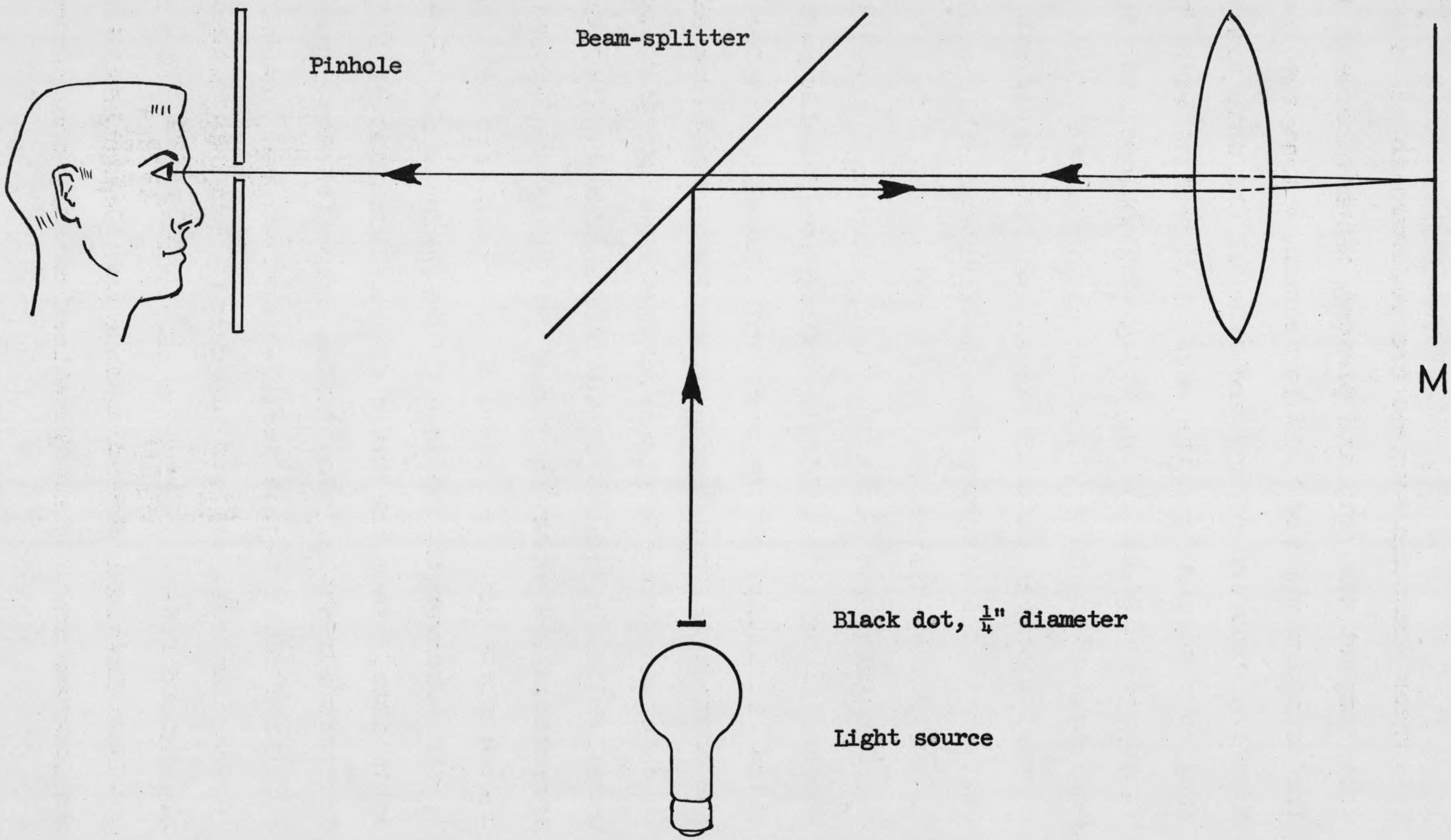


Fig. 33. Plotting Chip Tester

having colors run from one face to another. The method which proved most satisfactory was to drop from a small eyedropper a metered amount of properly prepared lacquer. Much experimental work went into finding proper combinations of dyes, lacquers and solvents to give the clear, bright, durable results desired. The following lacquer solutions were satisfactory:

a. Red: Paasche liquid weather resistant color diluted 5 to 1 with methyl cellosolve.

b. Yellow: Paasche orange mixed 2 to 1 with Paasche thinner.

c. Green: Thin pyroxcote 18-73-1 lacquer dissolved 1 to 4 in methyl cellosolve, then colored with powdered Azosol fast HLA green and Azosol fast yellow RCA NEW.

d. Blue: In a 15 ml test tube mix 2 ml pyroxcote 18-73-1 lacquer, 10 ml Glidden thinner (for Glidden industrial clear lacquer) and 36 drops Cado Flomaster transparent ink.

9. An arrowhead was outlined on the face of each chip with a small pointed scribe and the area filled with Switzer Brothers Glo-Craft pearl white lacquer enamel.

10. Small white paper numerals, of 3/16" size, were then cemented to each face with G-S Hypo-Tube watch crystal cement.

11. The white numerals were then painted with appropriate fluorescent lacquer enamel colors. For extreme

brightness, distinctive color and light fastness, the following were found most satisfactory:

a. Red: Glo-Craft neon red lacquer enamel.

b. Yellow: Sylvania CR-30 yellow fluorescent powder mixed with clear lacquer.

c. Green: Glo-Craft signal green lacquer enamel.

d. Blue: Sylvania CR-20 blue fluorescent powder mixed with clear lacquer.

EXCERPTS FROM OPERATIONS ANALYSIS MEMORANDUM NUMBER 3
(Hq. 9AF/OA/M-3)

EVALUATION OF PROJECT QUICK FIX

Prepared by:

RABUN M. WOOD
Operations Analyst

Approved by:

H. REESE IVEY
Liaison Analyst, Hq. TAC to Ninth Air Force

This Memorandum contains the results of a study performed by Operations Analysts. Results of this study are not to be considered in the nature of Ninth Air Force policy, but rather as a guide in future staff action. The findings and analyses are subject to revision as may be required by new facts or by modification of basic assumptions.

23 May 1953

HEADQUARTERS NINTH AIR FORCE
Pope Air Force Base
Fort Bragg, North Carolina

ABSTRACT

This memorandum contains the results of an operational analysis of a proposed system for the transmission, processing and display of radar information within the forward most portions of a Tactical Air Control System. The test program of the subject system carried out by the joint efforts of the Control Systems Laboratory of the University of Illinois, Headquarters Ninth Air Force, and the 507th Tactical Control Group during the period 14-24 April 1953. The equipment involved was produced by the Control Systems Laboratory, University of Illinois under ARDC Project QUICK FIX. The demonstrated QUICK FIX equipment embodies decided improvements in speed, fidelity and capacity of handling radar data within the Tactical Air Control System. Expeditious action should be taken for the immediate procurement and application of this equipment in order that the advantages of these improvements may be realized.

A. DISCUSSION

1. Features about which quantitative data were obtained are the speed, fidelity and capacity of the proposed system for displaying a clear (filtered) picture at the TADC from the unprocessed data provided by radar sets. These data were compared with simultaneously recorded data from corresponding points in the conventional tell-plot system. Both the QUICK FIX and the conventional system were supplied identical information from the same three radar sources. In addition, other operational features that affect the suitability of the demonstrated principles for Air Force use are evaluated on a qualitative basis. It should be emphasized, however, that this evaluation does not cover the scope of an Operational Suitability Test as normally conducted by APGC.

2. One method of obtaining quantitative data entailed the use of four still cameras which were used to make a series of twelve exposures, once a minute, simultaneously at each of four different points in the system. Radar scope photographs were made at the Laurinburg LWRU AN/TPS-1D site and at the Pope AN/CPS-5 site. These photographs gave measures of the inputs to the system. Outputs of the system were recorded by photographing the aircraft position plotting board in the conventional TADC and the projected clear picture in the QUICK FIX TADC. Both of TADC's were in operation and were supplied data by common inputs (radars).

It was necessary to make additional measurements in order to determine the time for the optical target position indicator (OTPI) chip pushers to post a plot by bringing the plotting chip into coincidence with the scope image, since this time was shorter than the exposure time required to take photographs. Special data were obtained by observing and timing the particular operation of chip-moving.

3. The highly favorable results of the tests warrant immediate staff action to obtain these improvements for the Tactical Air Control System. In order to expedite such action, the present report is limited to a presentation of test results. If further study of the data points out additional interesting facts, additional reports will be prepared. In the meantime, the basic data will be available for study in the Office of Operations Analysis at Headquarters Tactical Air Command.

B. RESULTS OF ANALYSIS

1. Advantageous Features Of The QUICK FIX System

a. Speed

(1) Only 1/8 of a second is required for the radar information to be transmitted from the radar site to the collection point. This delay compares with about two minutes in the conventional system measured during these tests, and with about 5 to 7 minutes as experienced in past operation of the currently used system. In addition to this 1/8 of a second, it has been determined from the film data

and from observing and timing the operations, that the time interval between receipt at the collection point and clear picture display is the order of one second for position data, and an interval that varies from zero to 15 seconds for direction data. This delay in direction data is peculiar to any radar of this type, because two scans (15 seconds in AN/TPS-1) are necessary for establishing an initial heading or a change in heading. With established courses and no changes, there is, of course, no delay in direction data. Once a course or change is recognized, the plot time is the same order and occurs simultaneously with that for position data. This results in an improvement of greater than 100 times, even for the low-traffic condition of the test period, and would result in even greater improvement ratio during periods of high traffic density. The target display speed will vary a small amount with operator proficiency and the number of targets assigned to a particular operator.

b. Fidelity

(1) The fidelity of the clear picture presented is dependent on two basic features:

(a) accuracy with which the display position coincides with the true position, and

(b) the speed with which the reported position is plotted on the display. Because the delay in display time for a particular target is very small, and because the differences in display times for different targets are even smaller, a true picture of the air situation is obtained, up to the capacity of the system. See paragraph B. 1. c. below.

(2) Accuracy obtained during the demonstration was the order of two miles for position data and 15 degrees for direction. It has been found that the fidelity of direction information varies more between operators than that of the position data. However, because the displayed direction does not necessarily control the next reported position, there is a certain amount of inherent correction derived despite the above noted error. Both position and direction data accuracy will vary with operator proficiency and traffic load, directional information being the more dependent.

(3) There was a tendency noted, by comparing the basic radar data with the displayed data, for the plotters to lead the target position a small amount in the QUICK FIX system (giving an apparent negative delay which is impossible).

(4) It is interesting to note that even with the relatively inexperienced operators used during the demonstrations, the clear projector picture was sufficiently true and up-to-date for Ground Controlled Intercepts to be conducted directly from the clear picture screen, i.e., the intercepting fighters were brought into position and range to visually acquire the target and complete the intercept.

c. Capacity

(1) The data contained in Table I, comparing the amounts of traffic information handled by the conventional and QUICK FIX systems was compiled from the film records for a ten-minute test period.

(2) From this table, direct improvements in various factors that affect capacity are seen. It is interesting to note that while the ratio of the total number of tracks reported between the QUICK FIX and the conventional systems was less than 2 to 1, the QUICK FIX system carried these tracks on the average 2 1/2 times longer, and at any given time, the QUICK FIX board was carrying about 2 1/2 times as many tracks. This is an indication of better continuity and reliability as well as capacity. The total number of plots in the QUICK FIX system was approximately 12 times greater than the number of plots in the conventional system for the same period of time. In the proposed system, each track carried was plotted an average of 19 times as against an average of less than 3 plots per track in the old system. The QUICK FIX system handled 40 to 50 plots per minute as against an average of 3.7 per minute in the old system for an improvement ratio of approximately 12. In addition, the elapsed time between plots was less than 1/5 as much for the QUICK FIX system as for the conventional system. This time between plots means that the reliability, i.e., the chance

SECRET

TABLE I

	Quick Fix	Conventional	Improvement Ratio
Total Tracks Reported On	23	13	1.77
Average Tracks Carried (per minute)	12.65	5.3	2.39
Average Length of Track	6.33 mins.	2.48 mins.	2.55
Total Number of Plots	Approx. 450	37	Approx. 12
Average Plots/Track	Approx. 19	2.85	Approx. 7
Average Plots/Minute	Approx. 45	3.7	Approx. 12
Average Time Between Plots	Approx. 18 secs.	98 secs.	5.45

SECRET

of receiving a needed position report is 5 1/2 times better. The most striking comparison that can be made concerns the elapsed time required for the travel of the basic radar information from the radar display to the clear picture display. The new system embodies an average delay of approximately one second. Even with the small amount of traffic carried in the old system, the corresponding time delay was more than 100 times as great. It was also demonstrated by the film data, that as traffic load increased, the delay in the conventional system would tend to become greater, increasing the improvement ratio of the QUICK FIX system over the old system several times more than improvements noted in the table above.

(3) Capacity is more dependent upon operator proficiency than had been first estimated, being more dependent than either speed or fidelity. In the cases of both the QUICK FIX and the conventional displays, the time sequence photographs showed that the number of targets being tracked was smaller than a visual examination of the display would indicate, due to the number of displayed targets that were not being kept up-to-date. The "concensus of " (sic) opinion among the operators was that one man was presently capable of tracking scan-by-scan at least 5 targets, as against 2 targets in the tell-plot system. This will vary a small amount with relative spacing of the targets and total traffic load, even with trained operators. It is believed that with proper training this figure can be raised.

SECRET

PERSONNEL ASSOCIATED WITH THE QUICK-FIX PROGRAM

A. Headquarters Ninth Air Force

Maj. Gen. E. J. Timberlake
Brig. Gen. J. Ferguson
Col. I. F. Stinson
Lt. Col. R. C. Garlich
Lt. Col. C. A. Baril
Lt. Col. M. Kovacevich
Maj. D. W. Baugher
Maj. J. C. Cuddington
Mr. L. F. Zakowski
Mr. R. M. Wood (on loan from Headquarters TAC)

B. 507th Tactical Control Group

Col. L. C. Heartz
Capt. J. C. Ferguson

C. 8th Communications Group

Col. H. Riera
Maj. J. C. Smith
Capt. E. H. Keiser
Mr. Deneff

D. 728th AC & W Squadron

Maj. J. R. McNamara
Maj. F. S. Puente
Capt. A. J. Downing
Capt. S. Lesko
Capt. J. L. Briley
Capt. D. E. Ulstad
Capt. H. E. Wells
1/Lt. J. E. Currie, Jr.
1/Lt. J. B. Killebrew
1/Lt. J. Tucker
2/Lt. R. M. Gilliam
2/Lt. R. C. Alexander
2/Lt. H. F. Karon
Mr. R. Tromblay
M/Sgt. J. D. Paul
M/Sgt. W. S. Bridges
T/Sgt. T. E. Lattie

T/Sgt. H. D. Hensley
T/Sgt. B. J. Kappes
T/Sgt. J. W. Nickerson
T/Sgt. J. R. Forget
S/Sgt. E. R. Rossi
S/Sgt. R. G. Cail
S/Sgt. R. G. Lake
S/Sgt. J. G. Smith
S/Sgt. L. E. Owens
S/Sgt. R. F. Vanney
S/Sgt. R. R. Church
S/Sgt. J. O. Delk
S/Sgt. R. A. Hoopengarner
S/Sgt. R. W. Kies
S/Sgt. A. G. Phillips
S/Sgt. S. G. Glidewell
S/Sgt. W. T. Clark
A/1C J. A. King
A/1C Z. Landis
A/1C W. T. Sommer
A/1C R. D. Richardson
A/1C E. W. Townson, Jr.
A/1C M. J. Augustin
A/1C W. R. Brown
A/1C E. R. Bykowicz
A/1C P. J. Forster
A/2C G. Gray
A/2C H. A. Sokolik
A/2C J. J. Brennan, Jr.
A/2C V. L. Shropshire
A/2C H. E. Griffin
A/3C J. H. Trogdon, Jr.

E. Rome Air Development Center

Lt. Col. J. S. Lambert
Mr. H. Friedman

SECRET

COPY OF QUICK-FIX VISITORS LOG

April		NAME	RANK	ORGANIZATION	JOB TITLE
8	1.	John C. Ackerman	Civilian	Evans Lab - SEEL	Asst Chief Systems Sect
	2.	Charles Grossman	Civilian	" " "	Project Engineer
	3.	J. B. McKenzie	Lt Col	Jt Tac Spt Board	Acting Officer
9	4.	K. C. Dempster	Col USAF	" " "	Doctrine Department
	5.	L. T. Blake	Lt Col USAF	" " "	Equipment Department
	6.	B. B. Townsend	Lt Col	" " "	Doctrine
	7.	R. C. Ross	Maj Sig C	" " "	Equipment
10	8.	Henry Riera	Colonel	8th Comm Group	Commanding Officer
	9.	James C. Smith	Major	8th Comm Group	Operations Officer
	10.	Joseph G. Calder	Major	727th AC&W Sq	TADC Commanding Officer
	11.	Harold H. Duncan	Civilian	727th AC&W Sq	Philco Tech Rep
	12.	Roger F. Freggens	Lt Col	Hq 9th Air Force	C & E Plans
	13.	John J. Cunningham	Lt	727th AC&W Sq	Radar Maintenance
	14.	Roy D. Alberts	2nd Lt	727th AC&W Sq	" "
	15.	J. M. Morgan	1st Lt	727th AC&W Sq	" "
	16.	Arthur L. Tennentaum	Civilian	727th AC&W Sq	Tech Rep
	17.	E. W. Barnes	Maj Gen	Office Secy of Defense	Member
	18.	L. E. Oliver	Major	507th Tac Con Gp	S - 3
	19.	C. A. Baril	Lt Col	Hq 9th Air Force	C & E Plans
	20.	W. P. McBride	Colonel	Office Secy of Defense	Member
	21.	J. K. Jennings	Major	Hq 9th Air Force	Communications & Elect
	22.	D. W. Baugher	Major	Hq 9th Air Force	" "
	23.	James C. Cuddington	Major	Hq 9th Air Force	" "
14	24.	R. J. Ruick	Lt Col	157th Tac Con Gp	Commanding Officer
	25.	J. M. Dunn	Capt	157th Tac Con Gp	Deputy for Personnel
	26.	C. Brown	Lt Col	AFF Board #1	Test Officer
	27.	O. G. Mullison	Capt	157th TCG-Alex AFB	Operations Officer
	28.	O. Capo-Ferri	Civilian	" " " "	Philco Tech Rep
	29.	C. Stack	Capt	" " " "	CO, 124th AC&W Sq
	30.	L. Spoonts	Major	" " " "	Operations Officer
	31.	G. J. Higgins	Maj Gen	82nd Abn Division	Commanding General

SECRET

SECRET

	32.	L. C. Heartz	Colonel	507th Tac Con Gp	Commanding Officer
	33.	R. D. Baskerville	Major	727th AC&W Sq	Commanding Officer
	34.	H. W. Powell	Capt	729th AC&W Sq	Commanding Officer
	35.	J. W. Morris	Capt	729th AC&W Sq	Operations Officer
	36.	A. DeLucia	Civilian	RADC	
	37.	W. S. Penn	1st Lt	82nd Abn Division	ADC
	38.	M. Lippman	Capt	507th Tac Con Gp	Operations
	39.	L. W. Chapman	1st Lt	729th AC&W Sq	Controller
	40.	James Osborne	Capt	727th AC&W Sq	C & E
	41.	J. E. Demenles	1st Lt	729th AC&W Sq	Controller
	42.	W. G. Kearl	1st Lt	" " "	Elect
	43.	R. P. Bessy	Capt	RADC	Elect
	44.	A. J. Beauchamp	Civilian	RADC	Electronic Engineer
14	45.	L. J. Cahill	Major	Hq 9th Air Force	Communications & Elect
	46.	B. W. Smith	Capt	507th Tac Con Gp	" "
	47.	J. Solis	Capt	82nd Abn Division	D.S.S.O.
	48.	J. E. Simpson	M/Sgt	" " "	"
	49.	G. C. Hendricks	Capt	507th Tac Con Gp	Communications & Elect
	50.	J. E. Sackett	M/Sgt	" " "	S. M. Team
	51.	K. W. Howat	Lt Col	Hq 9th Air Force	Plans
	52.	John Gifford	Lt Col	" " "	"
	53.	J. T. Van Patten	Major	" " "	"
15	54.	L. J. Manor	Major	Air Grd Opns Sch	Instructor
	55.	P. F. Hedricks	Colonel	Hq, AEDC	DCS/M
	56.	H. W. Berry	Lt Col	OC Signal Corp	D/A Coord JCEC
	57.	K. L. Sharkey	Capt	Hq 18th Air Force	Elect Maint Officer
	58.	G. E. Clark	Major	47th Inf Division	Executive Officer
	59.	I. D. Wilson, Jr.	Major	Hq. U.S.A.F.S.S.	Ex. O.D./CS/Ops
	60.	R. R. Cowgill	Major	Hq, 167th FBS	Materiel Officer
	61.	William H. Sheppard	Lt Col	16th Sig Bn Corps	Commanding Officer
	62.	Joe H. Underwood	Major	31st Med Tng bn Camp Roberts, Calif	Battalion Cmdr
	63.	E. R. Hemmingway	Lt Col	USMC MAG-24	S - 3
	64.	R. M. Dixon	Capt	ANG, 162nd Ftr Sq	Flight Cmdr
	65.	John R. Magnusson	Lt Col	Hq, TAC, 4050 ASU	G - 1
	66.	W. J. Smith	Colonel	Air War College	Instructor
	67.	C. L. Enic	Lt Col	US Army	S - 3

SECRET

43-131/139
Appendix V

SECRET

15

68.	Stockton D. Bruns	Lt Col	US Army	
69.	Jesse L. Lishback	Lt Col	US Army	Instructor
70.	C. B. Claypool	Lt Col	Jt AMPN Bd, USA Secretary	TC adviser
71.	John D. Highby	Major	Air University	Instructor
72.	A. G. Sullivan	Capt	5010 ASU	
73.	Earl M. Cunard, Jr.	Capt USMC	TES, Ft Belvoir, Va	"
74.	B. W. Kalbert	1st Lt	Div. TAS, 1st A.D. Ft. Hood, Texas	ADT
75.	James F. Harry	Capt	59 bn AAA&GM, Ft Bliss, Texas	Executive Officer
76.	D. H. Phillips	1st Lt	366th FBW, Alex AFB	Pilot
77.	Alfred R. Schonely	2nd Lt	167th AFA Bn Ft Sill	Forward Observer
78.	Robert P. Wayne	Capt	Hq, 6AAA Group	S - 2
79.	Ray W. Fletcher	Civilian	Hq, USAF Security Service	
80.	Sam J. Matthews	Capt	153rd Infantry	S - 3
81.	D. W. Weed	Civilian		
82.	W. A. Davenport	2nd Lt	366th FBW, Alex AFB	
83.	Walter A. Robinson	1st Lt	4425th School Sq Southern Pines, N.C.	Transportation Officer
84.	Robert W. Park	Major	Camp Chaffee	Bn Cmdr
85.	W. G. Maher	Major	Hq 1st Guided Missile Brigade, Ft Bliss, Texas	S - 1
86.	L. K. Robinson	Major	Hq 233 FA Bn	Bn Cmdr
87.	E. Mason	Capt	122nd Bmr Sq	Flight Leader
88.	A. J. Brigham	Major	111th Armd Cal	Bn S - 3
89.	J. P. Coakley	Capt	A6S Ftr Relay	Instructor
90.	Emerson W. Smith	Major	Hq 38th Inf Div	G - 3 AIR
91.	A. L. Bosworth	Lt	479th Ftr Bmr Wg	Pilot
92.	W. G. Trislire	Lt	" " " "	"
93.	A. G. Haydale	Lt Col	USMA	"
94.	C. L. Stafford	Colonel	Hq USAF	Student
95.	H. G. Barber	Lt Col	Army	"
96.	W. H. King, Jr	Lt Col	Army	"
97.	J. S. Mitchell	1st Lt	USAF	"
98.	H. N. Waskow	Capt	Army	"

SECRET

SECRET

15 99.	J. W. Saxton	Major	390th FB Sq	Pilot
100.	G. H. Jennings	Major	OCAFF	Student
101.	Irvin Sprague	Capt	Air National Guard	Asst S - 3
102.	A. C. Edmenton	Major	Hq 140th In	Executive Officer
103.	J. H. Miller	Capt	ILS, Ft Benning	Instructor
104.	John J. Bogan			
105.	Thomas F. Cane, Jr.	Lt Col	USMC	Operations
106.	William R. Bortz	Lt Col	USAF	
107.	James W. Olley	Capt	170 FA Bn NY NG	Bn S - 3
108.	Leland B. Jones	Colonel	178th	Commanding Officer
109.	Harry W. Geverous	Colonel	AFMTC ARDC	I.G.
110.	Monto L. Peterson	1st Lt	Army - US	Commanding Officer
111.	Ralph Spencer, Jr.	1st Lt	Air National Guard	Pilot
112.	L. L. Fisher	Lt Col	USAF	Executive Officer
113.	A. Babunhin	Capt	US Army	S - 2
114.	John J. Hanretty	Capt	82 Abn Division	G - 2
115.	Arthur Brunson	Major	G2, DA	G - 2
116.	Stanley H. Casey	Major	S-2 153rd Inf	S - 2
117.	William J. Gibson	1st Lt	21st FB Wing	Pilot
118.	Maurice E. Hordhund	Capt	" " "	Pilot
119.	W. H. Beckett	Capt	USAF	Pilot
120.	W. K. Roberts	Major	AFSWP	Instructor
121.	A. W. Mitchell	Lt Col	Ft Benning, Ga.	Battalion C.O.
122.	J. E. Wilson	Capt	463rd TCW Memphis	Flight Leader
123.	V. S. Atwood	Major	Hq 15th Cal Gp, Ft Knox, Tenn	S - 3
124.	R. C. Burnstein	Capt		
125.	Sidney Green	Civilian	Wright-ADC Ohio	Engineer - Project
126.	Ian Waller	Capt	2nd Bn, 1st OCR Ft. Benning, Ga.	Asst Ex Officer
127.	Edmund B. Edward	Lt Col	USAF, Lake AFB	F 84 Sq, CO
128.	J. C. Gray	Lt Col	11th Abn Division	Executive Officer
129.	J. O. Johnson	2nd Lt	389th Ftr Bmr Sq	Pilot
130.	L. A. Clough	Major	GFSS Nav Phi Base Little Creek, Va.	Instructor
131.	L. Lipmann	Major	AC&SS Maxwell AFB	Instructor
132.	R. E. Griffith	Capt	Air Weather Sta	Training Officer

SECRET

43-133/139
Appendix V

SECRET

133.	Joseph C. Vega	Major	AC & SS AU	Instructor
134.	P. J. Hidney	1st Lt	Hq XVIII Corps	Student
135.	Jim J. Witmein	Lt Col	Hq M & CWTC	Executive Officer
136.	Joseph H. Harrison	Lt Col	AFF Board No. 1	Division Director
137.	Raymond S. Dairs	Capt	Hq 720th FA Bn	Hq, Btry CO
138.	Roderic Hill	Lt Col	2nd Bn 111th Armd Cal	Battalion, CO
139.	James N. Goreham	Capt	5108 ASU MONG	Army Instructor
140.	Duane S. Larson	Capt	178th Ftr Intep Sq	Operating Officer
141.	G. L. Carlson	2nd Lt	479th Ftr Bmr Wg	Pilot
142.	E. A. Hlavue	Civilian		
143.	A. A. Marston	Major		
144.	W. D. Robon	Major	Jt Abn Trp Board	
145.	Hart Kart	Cdr	U.S.N. CTCD 22	Commanding Officer
146.	L. E. Chideosen	Capt.	44th Div Arty	S - 2
147.	W. P. Whelihan	Colonel	Jt Tac Air Spt Bd	
148.	C. C. Sloane	Colonel	" " " "	
149.	W. Dupe	Colonel	" " " "	
150.	E. S. Davis	Colonel	" " " "	
151.	W. E. Hines	Lt Col	" " " "	
152.	W. B. Fabrick	Cdr	" " " "	
153.	C. M. Forman	Lt/Cdr	" " " "	
154.	J. G. Johnson	Lt/Col	" " " "	
155.	L. K. London	Lt/Col	" " " "	
156.	T. S. Price	Lt/Col	" " " "	
157.	W. L. Licunette	Lt/Col	" " " "	
158.	F. R. Sibert	Colonel	" " " "	
159.	C. L. Wesolowsky	Major	" " " "	
160.	I. W. Boswell	Lt/Col	" " " "	
161.	D. E. Simons	Capt	" " " "	
162.	J. B. McKenzie	Lt/Col	" " " "	
163.	W. R. Wolfinbarger	Maj Gen	" " " "	
164.	L. W. Sills	T/Sgt	" " " "	
165.	J. P. Cordova	Major	Hq, 9th Air Force	NAFPI
166.	H. Harlow	Capt	1st Photo Sq	Photographer
167.	T. G. Akers	T/Sgt	" " "	"

SECRET

SECRET

	168.	W. T. McDonald	T/Sgt	1st Photo Sq	Photographer
	169.	J. H. Bruce	Capt	101st Tac Con Sq	Sr. Controller
	170.	A. M. Laewenthal	Major	151st Tac Con Gp	Controller
	171.	R. N. McDaniel	Lt Col	" " " "	Commanding Officer
16	172.	E. O. Lindblom	Lt Col	Hq 8th Comm Gp	Dept CO
	173.	N. S. Etkin	Major	Hq 9th Air Force	AOB
	174.	P. W. Vereen	Major	" " " "	Intelligence
	175.	C. F. Leo	Major	151st Tac Con Gp	
	176.	L. F. Nullens	Capt	" " " "	
	177.	K. A. Johnson	Major	Hq 9th Air Force	Communications & Elect
	178.	A. H. Taylor	M/Sgt	" " " "	" "
	179.	S. M. Newman	Capt	" " " "	Intelligence
	180.	S. H. Howell	Lt Col	" " " "	Director of Intelligence
	181.	R. R. Reich	Capt	" " " "	Communications & Elect
	182.	D. L. Crimmins	A/2c	" " " "	" "
	183.	S. C. Dyke	Major	507th Tac Con Gp	
	184.	E. F. Bagley	Major	" " " "	
	185.	L. E. Oliver	Major	" " " "	S - 3
	186.	J. H. Brown, Jr	Lt Col	Hq 9th Air Force	NAFDO
	187.	G. F. Blood	Lt Col	" " " "	Director of Plans
	188.	L. A. Walker, Jr	Colonel	" " " "	Director O & T
17	189.	J. R. Sharp	1st Lt	" " " "	NAFOI
	190.	T. S. Cutting	Lt Col	Hq Tac Air Command	Director AI
	191.	C. W. Steinkamp	Major	" " " "	Chief Electronics
	192.	J. V. Ulrich	Lt Col	Hq,Tac Air Command	Director P/E
	193.	F. P. Baker	Capt	" " " "	Comm. Supply 18th AF
	194.	M. Fernandez	Colonel	" " " "	Director C & E
	195.	W. T. Quinlan	Civilian	" " " "	Operations
	196.	E. H. Alexander	B/Gen	" " " "	Commanding General
	197.	J. A. Duganne	Lt Col	" " " "	Director of Requirements
	198.	C. H. Jones	Major	" " " "	Director Elect System
	199.	E. D. Griswold	Major	" " " "	O & T
	200.	W. N. Manley	Major	" " " "	Communications System
	201.	B. M. Hackney	Lt Col	" " " "	Doctrine
	202.	C. S. Foster	Capt	" " " "	DCS/Plans
	203.	M. T. Edwards	Major	" " " "	Director Ops. Plans

SECRET

43-135/139
Appendix V

SECRET

204.	R. R. Laurence	Capt	Hq, Tac Air Command	Operations
205.	D. L. Howell	Capt	" " " "	DCS/C
206.	J. C. Moore	Major	Hq, Ninth Air Force	NAFCE - OEC
207.	J. T. Phillips	Capt	Hq, 507th TCG	C & E Staff
208.	S. W. Mayer	Major	726th Tac Con Sq	Commanding Officer
209.	E. T. Keith	Major	Hq, Tac Air Command	Chief Landline Proj.
210.	B. P. Howard	Major	" " " "	Director Mgmt Anal
211.	P. E. Wright	Lt Col	" " " "	Air Surgeon Office
212.	A. F. Quintin	Major	" " " "	Director Comm System
213.	M. Kaminsky	Lt	727th AC&W Sq	Electronics Officer
214.	F. Greenwald	Capt	" " "	Asst TADC Comm
215.	A. G. Rowley	Lt	2nd Liaison	Pilot
216.	C. M. Hallam	Colonel	AFF Board #1	
217.	D. J. Calidonna	Colonel	" " "	
218.	E. A. Grove	Colonel	" " "	
219.	R. G. Winckler	Lt Colonel	" " "	
220.	C. E. Roberts	Lt Colonel	" " "	
221.	A. D. Shattuck	Capt	" " "	
222.	B. T. Patten	Civilian	" " "	
223.	R. B. Coffim	Lt Col	" " "	
224.	J. B. Souder	M/Sgt	Hq 9th Air Force	NAFDM
225.	R. J. Barrus	2nd Lt	727th AC&W Sq	Controller
226.	R. J. Giehls	2nd Lt	" " "	"
227.	W. M. Seliger	2nd Lt	363rd Air Base Gp	
228.	E. J. Timberlake	M/Gen	Hq, 9th Air Force	Commanding General
229.	T. F. O'Keefe	Colonel	" " " "	NAFIG
230.	C. A. Appel	Lt Col	" " " "	NAFIG
231.	F. A. Sharp	Lt Col	" " " "	NAFIG
232.	P. D. Gill	Capt	" " " "	NAFIG
233.	Dr. M. Leygorek	Civilian	Johns Hopkins Univ	Project Chairman
234.	H. Friedman	Civilian	Rome Air Dev Center	Project Engineer
235.	C. S. Ridgway	Capt	Hq, 9th Air Force	NAFCE
236.	J. S. Lambert	Lt Col	Rome Air Dev Center	Chief Project RADC
237.	R. M. Wood	Civilian	Hq, Tac Air Command	Ops. Analysis
238.	C. J. Schlapkohl	Colonel	Jt Air Spt Board	Sr. Marine
239.	R. A. Glaeser	Lt Col	" " " "	

SECRET

SECRET

	240.	T. F. Meehan	Major	Hq, USAF	DCS/O AFOAC-E/A
	241.	D. H. Woodyard	Lt Col	Jt Tac Air Spt Bd	
	242.	J. M. Barnum	Lt Col	" " "	
	243.	L. R. Patrick	Lt Col	" " "	
	244.	C. T. Goldenberg	Colonel	Hq, 33rd ADC	Dep. Commander
	245.	H. M. Ogburn, Jr	Lt Col	" " "	D. O. P. R.
	246.	P. N. New	2nd Lt	728th AC&W Sq	Supply
	247.	R. D. Schooley	Capt	" " "	"
	248.	M. M. Kovacevich	Lt Col	Hq, 9th Air Force	Chief Communications Div
	249.	F. M. Carney	Capt	727th AC&W Sq	Director Ops.
	250.	G. H. Berg	Lt Col	Hq, U.S.A.F.	AFDRQ - TA/S DCS/O
	251.	B. H. Weston	Major	" "	AFDRD - TA
	252.	W. F. Chapman	Colonel	" "	" "
	253.	D. E. Bell	Major	729th AC&W Sq	Commanding Officer
	254.	R. G. Enticknap	Civilian	M. I. T.	
22	255.	H. L. Kinne Jr.	Colonel	Jt Tac Air Spt Bd	Member
	256.	C. F. Lyons	Lt Col	" " "	Member
	257.	R. O. McManas	Civilian	A.F.C.R.C.	
	258.	D. J. Crowley	Civilian	"	
	259.	M. E. Lowe	Civilian	"	
	260.	H. M. Cleveland	Capt	Hq, 9th Air Force	Office Grd Training
	261.	A. G. Durbeck	Lt Col	Jt Tac Air Spt Bd	Member
	262.	D. R. Lawson	Major	" " "	Member
	263.	R. R. Amerine	Lt Col	" " "	Member
	264.	M. H. Carlton	Lt Col	Hq, 9th Air Force	Office Grd Training
	265.	J. R. Brown	Lt Col	Jt Tac Air Spt Bd	Member
	266.	J. R. Metzdorf	Lt Col	" " "	Training Department
	267.	W. P. Wheliham	Colonel	" " "	Training Department
	268.	D. C. Benjamin	Lt Col	" " "	Equipment
	269.	H. A. Tesiler	Lt Col	" " "	Doctrine
	270.	R. V. Higdon	Civilian	Haller, Raymond & Brown	Pres
	271.	J. L. McLucas	Civilian	" " "	V. P.
23	272.	O. Goldberg	Civilian	Rome Air Dev Cen	Chief TAC Supply Lab.
	273.	F. R. Stauffer	Civilian	U. of M. W.R.R.C.	Res. Asst
	274.	R. H. Dishington	Civilian	Rand Corporation	Assoc. Engineer

SECRET

43-137/139
Appendix V

SECRET

275.	P. E. Byail	Capt	941st F.A.C. Sq	
276.	D. T. Hutchinson	1st Lt	" " "	
277.	F. W. Loomis	Civilian	CSL - U of Illinois	Director
278.	N. J. Miuilo	Civilian	Rome Air Dev Cen	Eng Aid
279.	F. M. Kelly	Civilian	" " " "	" "
280.	J. K. Cannon	General	Hq, Tac Air Command	Commanding General
281.	H. L. Sanders	M/Gen	" " " "	
282.	I. D. Snyder	B/Gen	" " " "	
283.	D.C.G. Schlenker	Colonel	" " " "	
284.	C. J. Dily	Lt Col	" " " "	
285.	E. J. Whelles	Major	" " " "	
286.	C. E. Fitfwater	Major	" " " "	
287.	D. F. Gorham	1st Lt	507th Tac Con Gp	
288.	M. H. Morse	1st Lt	" " " "	
289.	J. M. Schurb	2nd Lt	" " " "	
290.	G. L. Wehner	Civilian	Hq. ADC	Elect. Engineer
291.	M. C. Paul	Major	" "	
292.	W. F. Blaylock	Civilian	" "	
293.	P. L. Getzinger	Lt Col	OCAFF	R & D section
294.	W. Curry	Colonel	Hq Tac Air Command	Director Prog & Committ
295.	W. E. Rhynard	Colonel	" " " "	Director Sp. Weapons
296.	R. N. Baker	Colonel	" " " "	Plans
297.	G. C. Henshaw	Major	MCEB, MCS	Air Defense Air Con
298.	T. C. Hrust	Major	Hq, U.S.M.C.	Air Con Elect Section
299.	C. T. Risher	Major	AFF Board #1	Marine
300.	C. A. Brannon	Lt Col	Hq, APGC	Chief ADB/OTD
301.	F. E. Quinlan	Lt Col	" "	Chief Elect Division
302.	J. H. Madison	Colonel	OCAFF	D & T Control
303.	S. A. Becklek	Colonel	AFF Board #1	Executive
304.	S. J. Mancuso	Lt Col	AFF Board #4	Test Officer
305.	G. Flohil	Civilian	ONR/Navy Dept	Elect Engineer
306.	W. A. Connolly	Civilian	Navy Buships	" "
307.	A. E. Smith	Civilian	ONR/Navy	" Science
308.	J. I. Castleman	Civilian	ORD/Army	Elect Engineer
309.	S. S. Levine	Civilian	Navy Buships	" "
310.	D. C. Rogers	Lt Col	Naval Res Lab	Systems Division .

SECRET

311.	R. B. Whitley	Civilian	Naval Res Lab	Radio
312.	J. W. Sullivan	1st Lt	941st F.A.C. Sq	Communications Officer
313.	G. P. Joyce	Cdr	Nav Res Lab	Milit Application Branch
314.	M. G. Weiner	Civilian	" " "	Organization Section
315.	H. D. Allen	Cdr	" " "	Military Operations Br
316.	T. H. Hardy	Lt Cdr	" " "	" " "
317.	C. L. Gould	Capt	941st F.A.C. Sq	Fwd Air Controller
318.	J. B. Johnson	Capt	" " "	" "
319.	K. E. Jackson	2nd Lt	728th AC&W Sq	TADP Controller
320.	C. E. Sferra	2nd Lt	" "	" "
321.	R. L. Simmons	2nd Lt	" "	" "
322.	J. H. McDonald	2nd Lt	" "	" "
323.	C. Greenblum	Civilian	Evans Sig Lab	Engineer
324.	J. Belmonte	Civilian	" "	Engineer
325.	W. L. Blackburn	1st Lt	941st F.A.C. Sq	Adjutant
326.	A. G. Lincoln	2nd Lt	" "	S. O.
327.	J. L. Motley	Capt	Hq 9th Air Force	Fighter Operations
328.	J. R. McBrayer	Major	" "	" "
329.	E. A. Abbott	1st Lt	" "	Intelligence
330.	A. I. Lipman	Major	Hq 1st Log Comm	Signal Officer
331.	I. F. Stinson	Colonel	Hq 9th Air Force	Director of Comm & Elect
332.	N. I. Johnson	S/Sgt	" "	NAFCE
333.	P. G. Davis	S/Sgt	" "	"
334.	C. Childre	Colonel	18th Air Force	Special Asst C. G.
335.	M. Fernandez	Colonel	" "	Deputy for Comm

UNCLASSIFIED

UNCLASSIFIED